


Comisión Interamericana del Atún Tropical
Inter-American Tropical Tuna Commission

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Management Strategy Evaluation for bigeye tuna in the eastern Pacific Ocean

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Inter-American Tropical Tuna Commission

4th Meeting of the Working Group on Management Strategy Evaluation
Hybrid meeting, June 5th, 2026

Presentation outline

This presentation includes three parts: context, framework, and results

Part 1: context

Why management strategy evaluation, what fisheries, what already in place

Part 2: framework

Objectives, indicators, harvest control rules, and the simulation engine

Part 3: results

Performance, trade-offs, robustness, and limits.

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Why management strategy evaluation?

Traditional advice relies on stock assessment. MSE evaluates the *whole strategy* under various sources of uncertainty

Traditional approach:

- Short-term focus on annual catch quotas or effort limits
- Uncertainty restricted to assessment alone
- Time-consuming annual or multi-annual negotiation without pre-agreed rules

Management strategy evaluation:

- Data + analysis + HCR as one strategy
- Closed-loop simulations capture feedback between actions and population dynamics
- Integrate biological, observation, and implementation uncertainty
- Explicit objectives and performance indicators

Why management strategy evaluation?

The MSE for bigeye tuna in the EPO runs on *two parallel tracks*

Dialogue track:

IATTC-sponsored workshops familiarized managers and stakeholders with MSE concepts and collected input on:

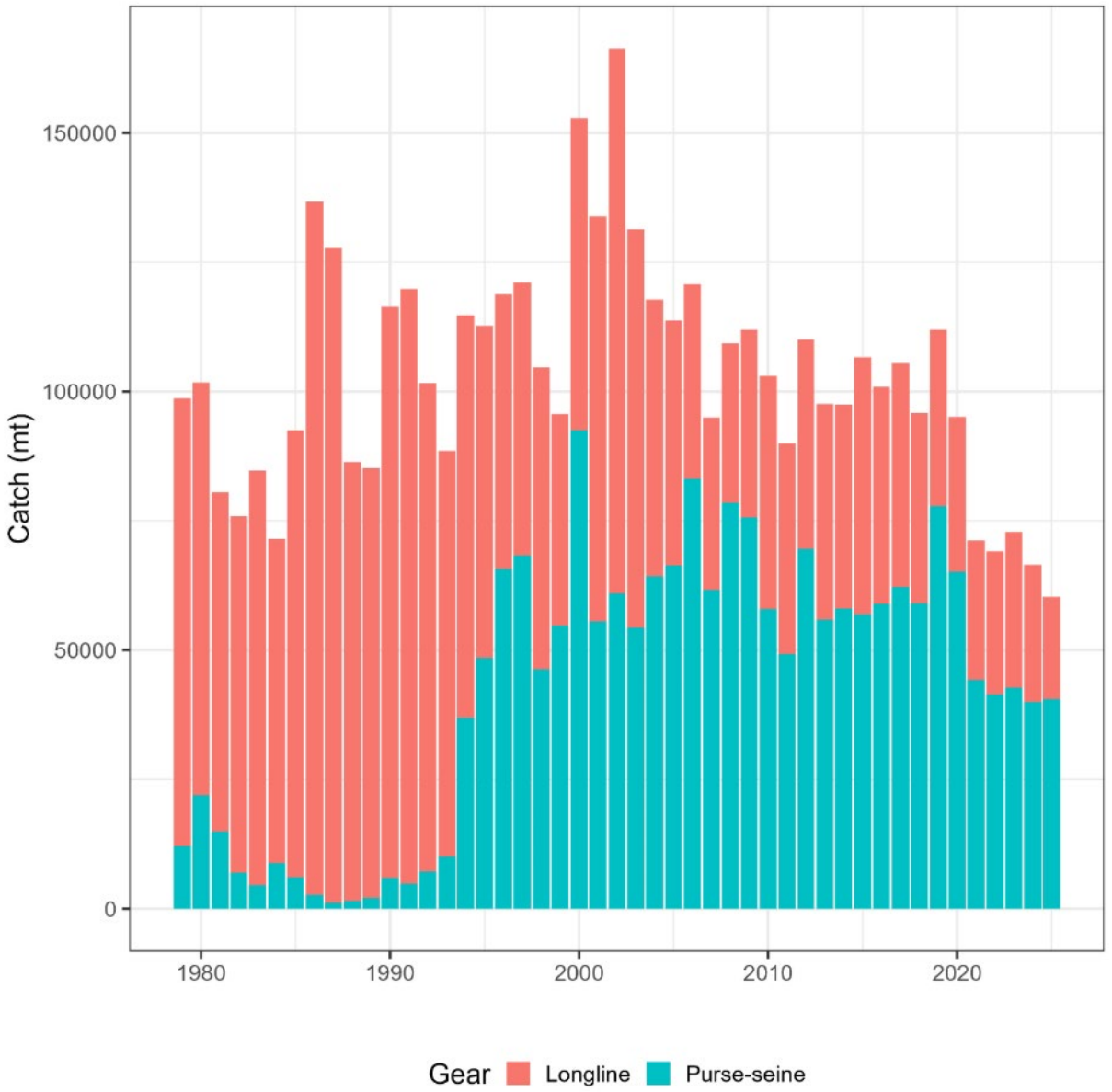
- Management objectives
- Performance indicators
- Candidate harvest strategies

Technical track:

IATTC scientific staff focused on:

- Developing and customizing simulation code
- Running simulations and calculating requested performance indicators
- Writing technical reports for the SAC
- Building online tools to communicate results

What fisheries harvest bigeye in the EPO?



- Until 1993, the distant-water longline fishery dominated bigeye catches in the EPO
- The floating-object fishery expanded rapidly in the early 1990s, replacing longline as the dominant contributor of bigeye catch.
- The longline share of catch dropped from 88% in 1993 to 23% in 2020

Current management framework

Purse-seine closures

Closure duration is set by the stock requiring the most restrictive management – historically, in most years, bigeye tuna

Longline limits

Total catch limit under Resolution C-21-04, allocated by CPC with limited transferability.

IVT (since 2022)

The individual vessel threshold measure intends to reduce juvenile bigeye mortality in the floating-object fishery.

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Potential management objectives

1: Safety

Stay above limit reference points

2: Status

Remain in the green Kobe quadrant

3: Stability

Limited interannual catch and effort fluctuations

4: Yield

Maintain catch at high levels

5: Effort

Keep the fishery open as much as possible

6: Abundance

Sustain longline CPUE above recent levels

Performance indicator: safety

Three limit reference points for the safety objective

Reference point	Definition	Performance indicator
0.2 dynamic SBR	The limit reference point for tropical tunas in the WCPO	Probability of dSBR falling below 0.2 (%)
0.077 SBR	SBR at 50% recruitment reduction under a steepness of 0.75	Probability of SBR falling below 0.077 (%)
0.5 S_{MSY}	Half the spawning biomass at maximum sustainable yield	Probability of S/S_{MSY} falling below 0.5 (%)

dynamic:
accounts for historical recruitment fluctuations

spawning biomass ratio:
spawning biomass / spawning biomass under no fishing

Performance indicator: status, stability, yield, effort, abundance

Each remaining objective maps to a specific indicator

Objective	Performance indicator
Status	Probability of remaining in the green Kobe quadrant (%)
Catch **stability**	Average annual variability in annual bigeye catch
Effort **stability**	Probability of having a 20-day closure increase in response to depletion
Purse-seine **yield**	Average annual purse-seine catch (mt)
Longline **yield**	Average annual longline catch (mt)
Purse-seine **effort**	Average closure for purse-seine (day)
Abundance	Ratio of average longline CPUE to the 2017-2019 baseline

Other performance indicators can be provided upon request

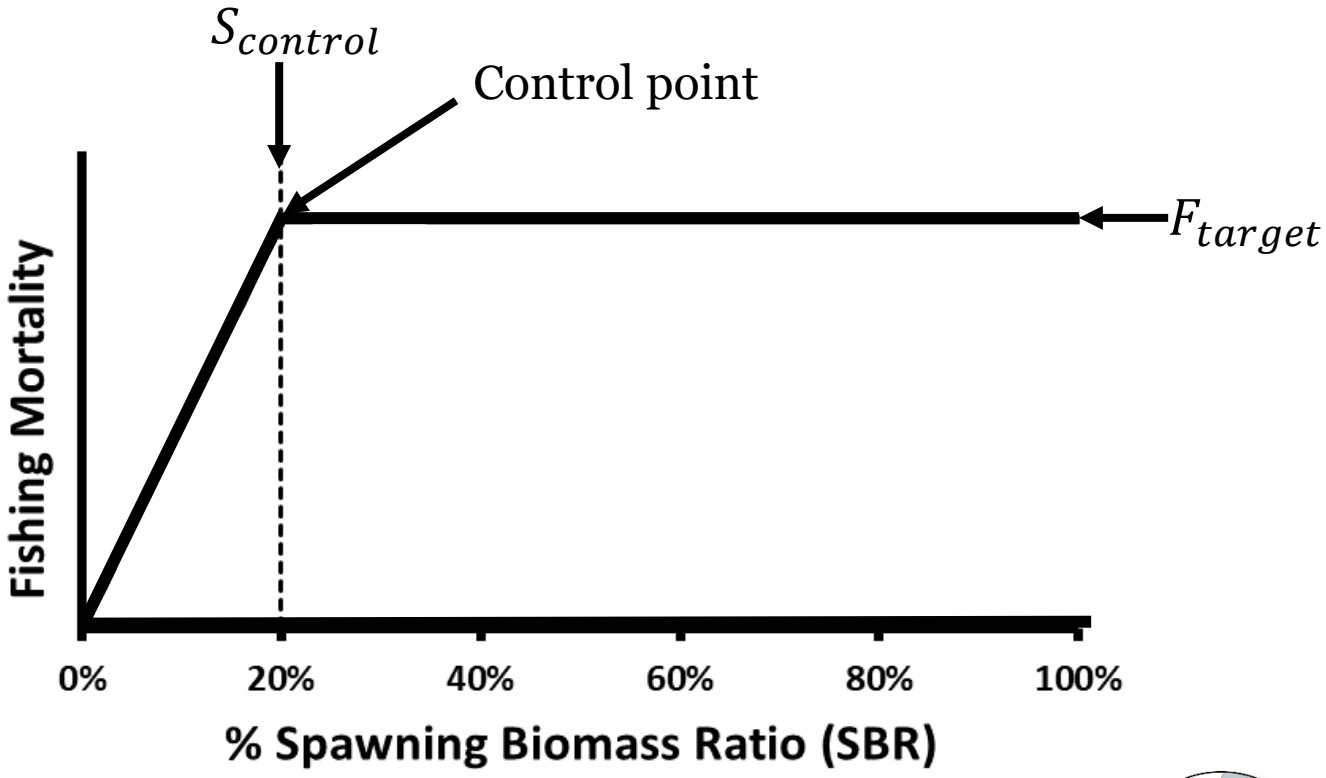
Candidate harvest control rules

HCRs have the same shape: flat above the control point, linear below

Fishing mortality is implemented using fishery closure:
F is proportional to 365 – days of closure

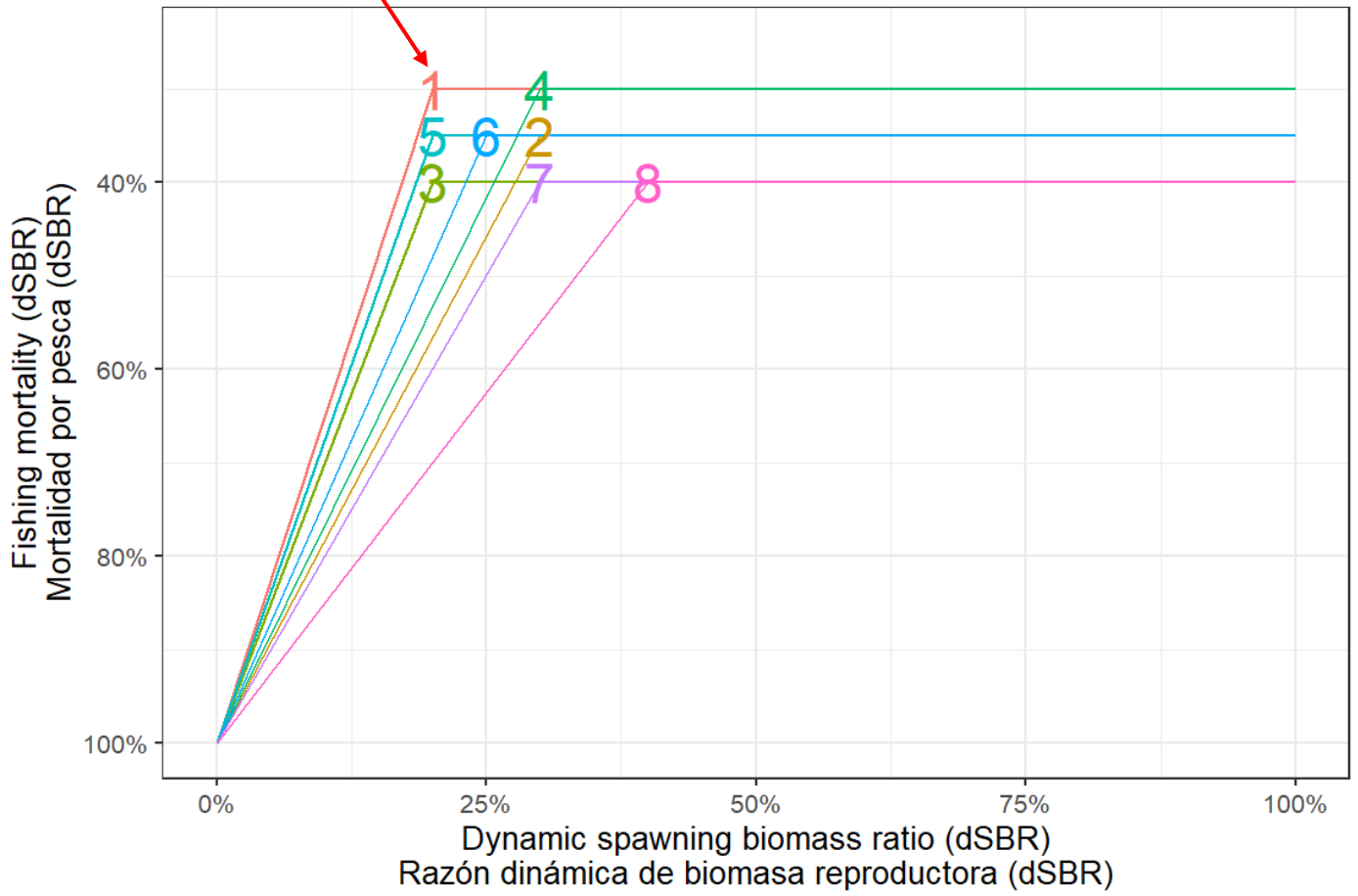
Above the control point ($S_{control}$):
- F stays at the target level (F_{target})
- Closure change is limited to -10 to 10 days

Below the control point ($S_{control}$):
- F decreases linearly to zero at zero biomass
- Closure change is limited to -10 to 20 days
- The asymmetry allows faster responses to depletion while preserving stability



Eight HCRs span three F-targets and four S-controls

Component	1 - Staff	2 - WG1	3 - WG2	4 - WG3	5 - WG4	6 - WG5	7 - WG6	8 - WG7
F_{target}	$F_{30\%}$	$F_{35\%}$	$F_{40\%}$	$F_{30\%}$	$F_{35\%}$	$F_{35\%}$	$F_{40\%}$	$F_{40\%}$
$S_{control}$	20%	30%	20%	30%	20%	25%	30%	40%
Name	F30-S20	F35-S30	F40-S20	F30-S30	F35-S20	F35-S25	F40-S30	F40-S40



MSE framework: operating models

An ensemble of 36 operating models represents plausible truths

- Come from the 2024 benchmark assessment / risk analysis
- Updated in 2025 with an additional year (2024) of fishery data to more accurately represent current stock and fishery status

Hierarchy level 1 (x4)

Misfit to longline length compositions

Hierarchy level 2 (x3)

Longline effort creep (0% / 1% / 2%)

Hierarchy level 3 (x3)

Stock-recruit steepness (1.0 / 0.9 / 0.8)

MSE framework: estimation models

A tuned ASPM_Rdevs+ acts as the estimation model

- ASPM_Rdevs+: Age-Structured Production Model that includes recruitment deviations and is fit to the index as well as selected length composition data
- The estimates of fishing mortality and dynamic SBR are tuned by 0.833 and 1.163, respectively, before being applied to the HCR
- The two tuning scalers are the ratios of weighted terminal estimates from the OM ensemble to the EM, ensuring consistency between the EM and the OM ensemble

MSE framework: specifications

The simulation horizon spans roughly six bigeye generations

Conditioning period	Projection period	Management cycle	# iterations per HCR
1979-2024 (updated in 2025)	2025-2046 (21 years)	3-year duration (7 cycles per MSE run)	1,200 (4 x 3 x 100)

MSE framework: specifications

The simulation includes various sources of uncertainty

Biological uncertainty

Recruitments lognormally distributed with zero bias and a standard deviation of 0.6 (consistent with OMs)

Observation uncertainty

The index has the same CVs as those for 2022-2024

Length compositions have the same sample sizes as those for 2017-2019

Implementation uncertainty

Implementation errors are lognormally distributed with zero bias and a standard deviation of 0.1 (constant within a management cycle)

All sources of uncertainty are simulated to be random and independent

MSE framework: algorithm and code

- A flexible MSE code tailored to tropical tunas in the EPO has been developed in R:
  - Publicly available as a R package: https://github.com/HaikunXu/IATTCMSE
  - Allows for parallel computation that can significantly speed up simulations
  - Built partially based on some existing MSE functions for NPALB and PBF
  - The algorithm of the MSE is described in detail in SAC-06-10b

- A R-shiny app has also been developed to show results interactively
  - Publicly available (bilingual): https://haikun-xu.shinyapps.io/MSE_BET_EPO/
  - All figures included in SAC-17-05 can be found in the app

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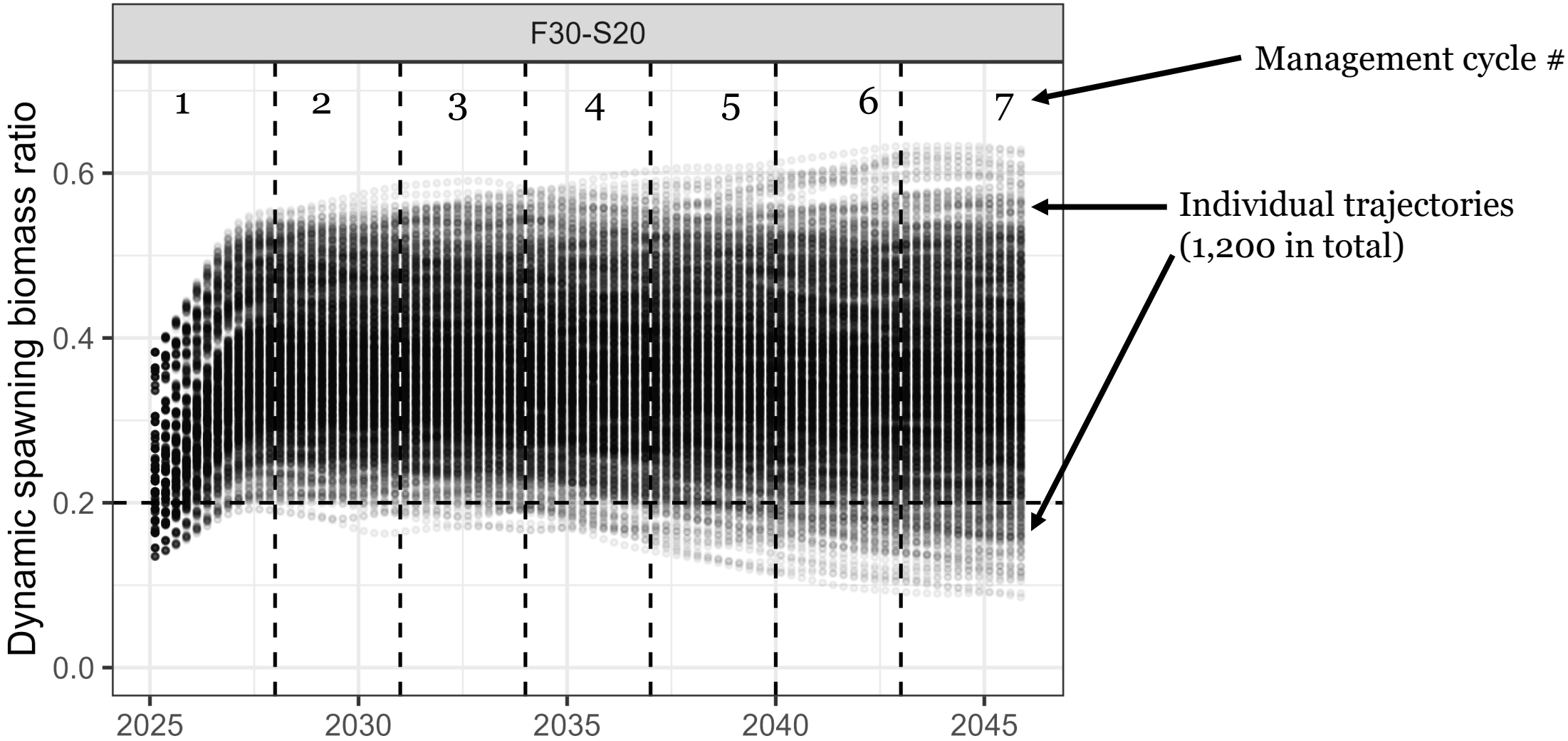
Results: dynamic SBR – how to read this figure?



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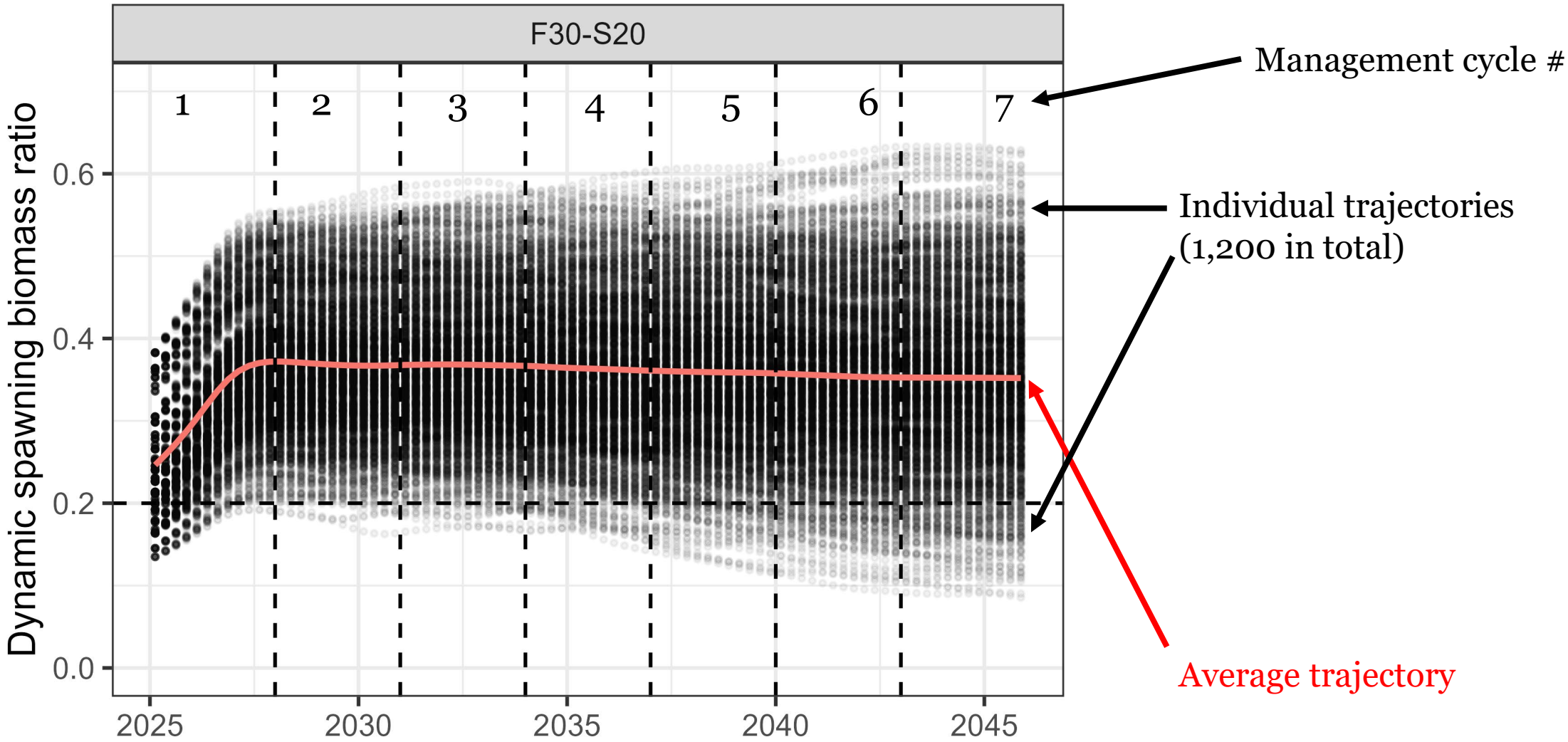

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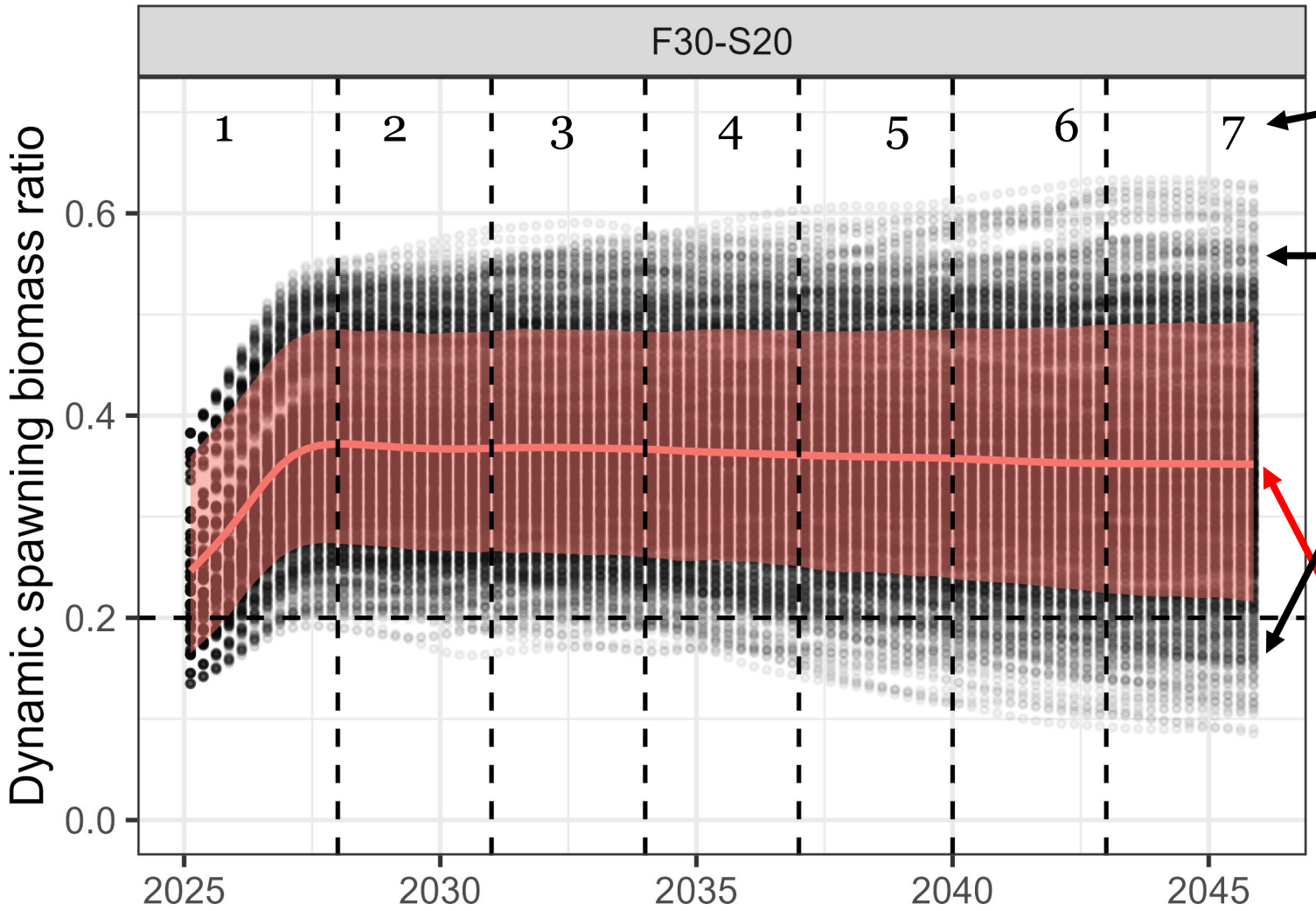


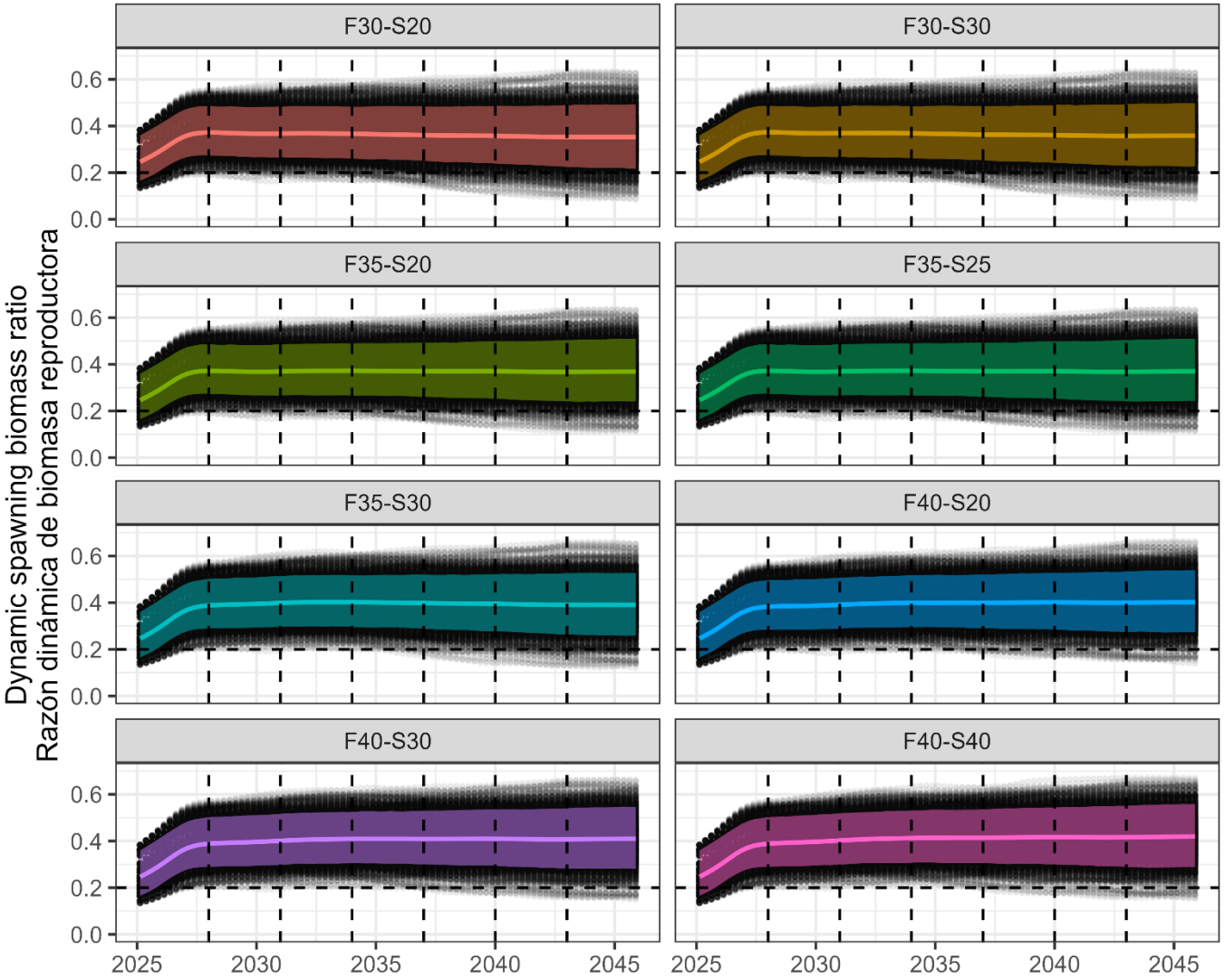
Management cycle #

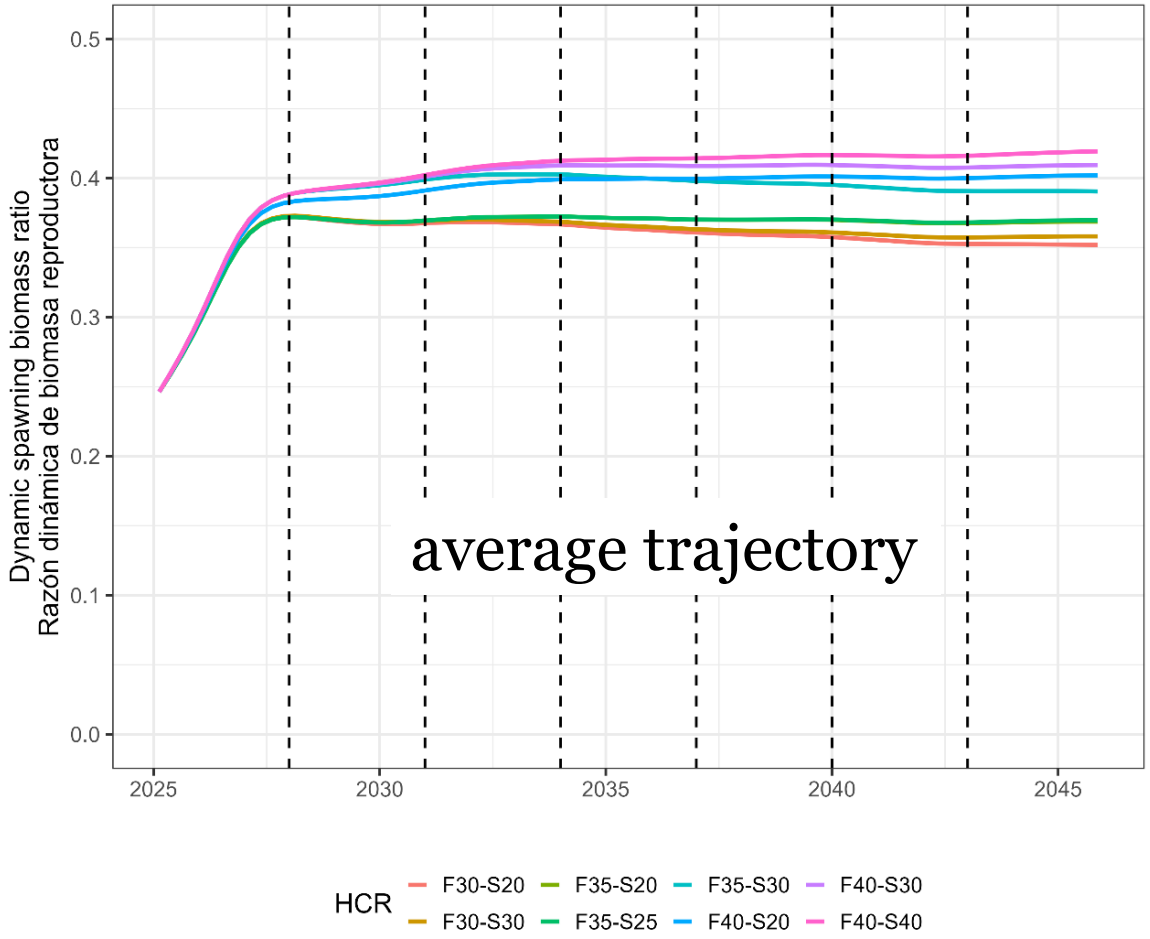
Individual trajectories
(1,200 in total)

10% to 90% percentiles
(covers 80% of individual trajectories)

Average trajectory

Results: dynamic SBR





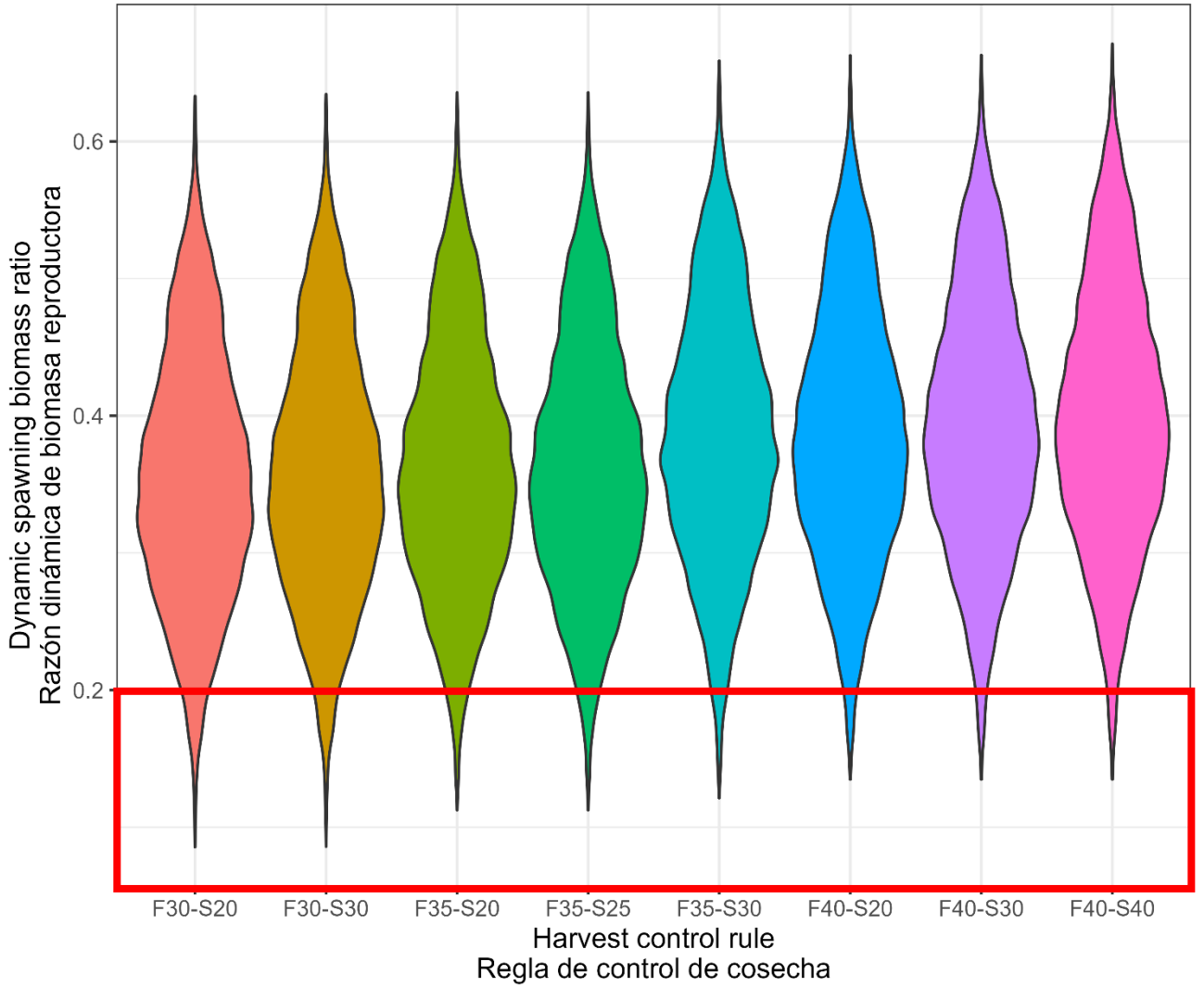
Performance indicators

Management objective	Performance indicator	Unit	Description
Safety	$p(dSBR < 0.2)$	%	The probability that dynamic spawning biomass ratio falls below 0.2
	$p(SBR < 0.077)$	%	The probability that equilibrium spawning biomass ratio falls below 0.077
	$p(S/S_{MSY} < 0.5)$	%	The probability that spawning biomass falls below 50% of the spawning biomass at the maximum sustainable yield
Status	$p(Kobe\ in\ green)$	%	The probability that the stock is in the green Kobe quadrant
Stability	$AAV(catch)$	%	Average annual variability in annual catch
	$p(closure + 20)$	%	The probability that the closure will increase by 20 days
Yield	$PS\ catch$	ton	Average annual purse-seine catch
	$LL\ catch$	ton	Average annual longline catch
Effort	$closure$	day	Average fishery closure
Abundance	$CPUE$	%	The ratio of average longline CPUE to the average level for 2017-2019

Performance indicators: safety

The probability that dynamic spawning biomass ratio falls below 0.2

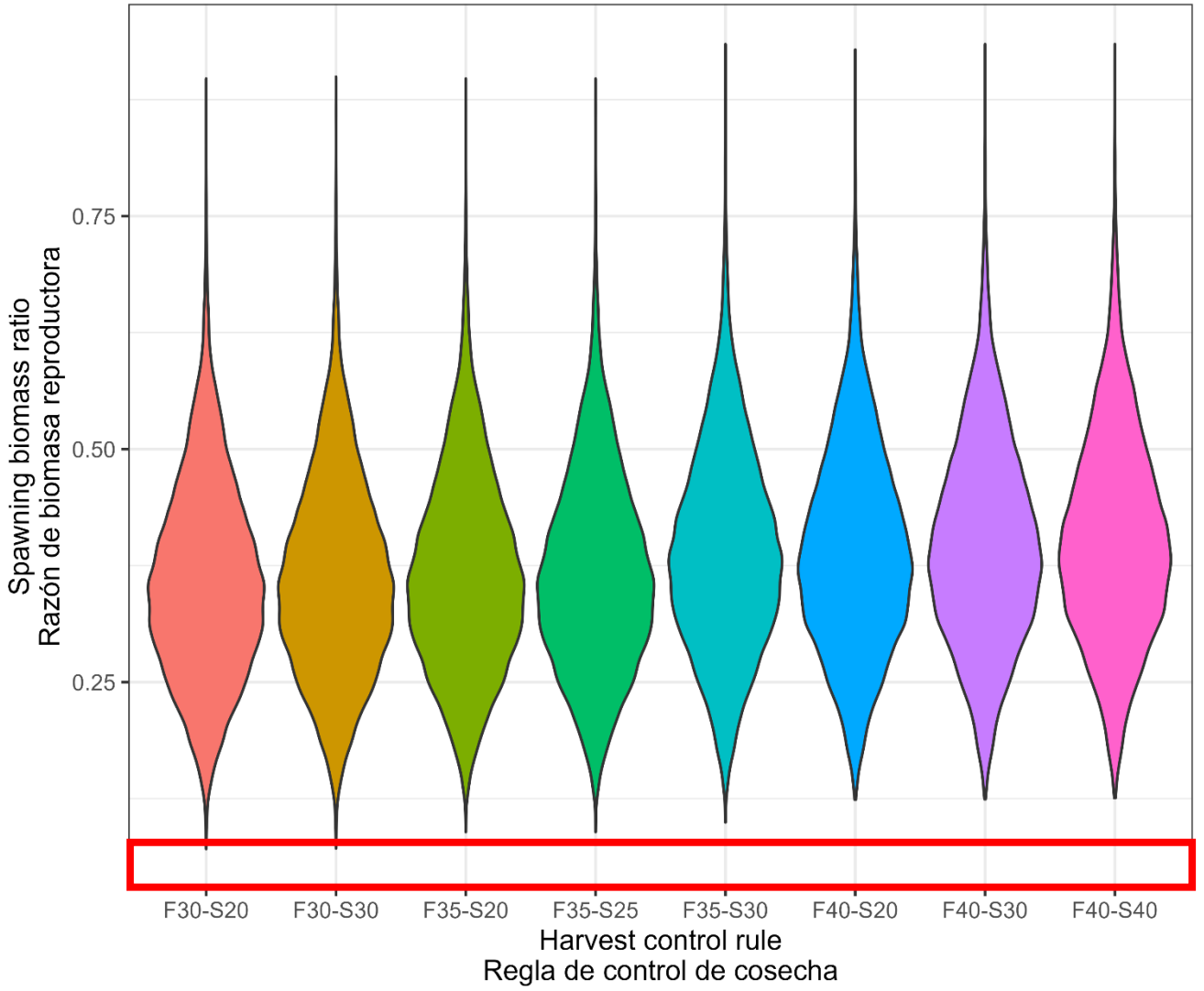
HCR	**Prob (%) dSBR < 0.2**	Prob (%) SBR < 0.077	Prob (%) $S/S_{MSY} < 0.5$
F30-S20	**3.5**	0.1	0.1
F30-S30	**3.3**	0.1	0.1
F35-S20	**2.5**	0	0
F35-S25	**2.5**	0	0
F35-S30	**1.7**	0	0
F40-S20	**1.5**	0	0
F40-S30	**1.3**	0	0
F40-S40	**1.2**	0	0



Performance indicators: safety

The probability that equilibrium spawning biomass ratio falls below 0.077

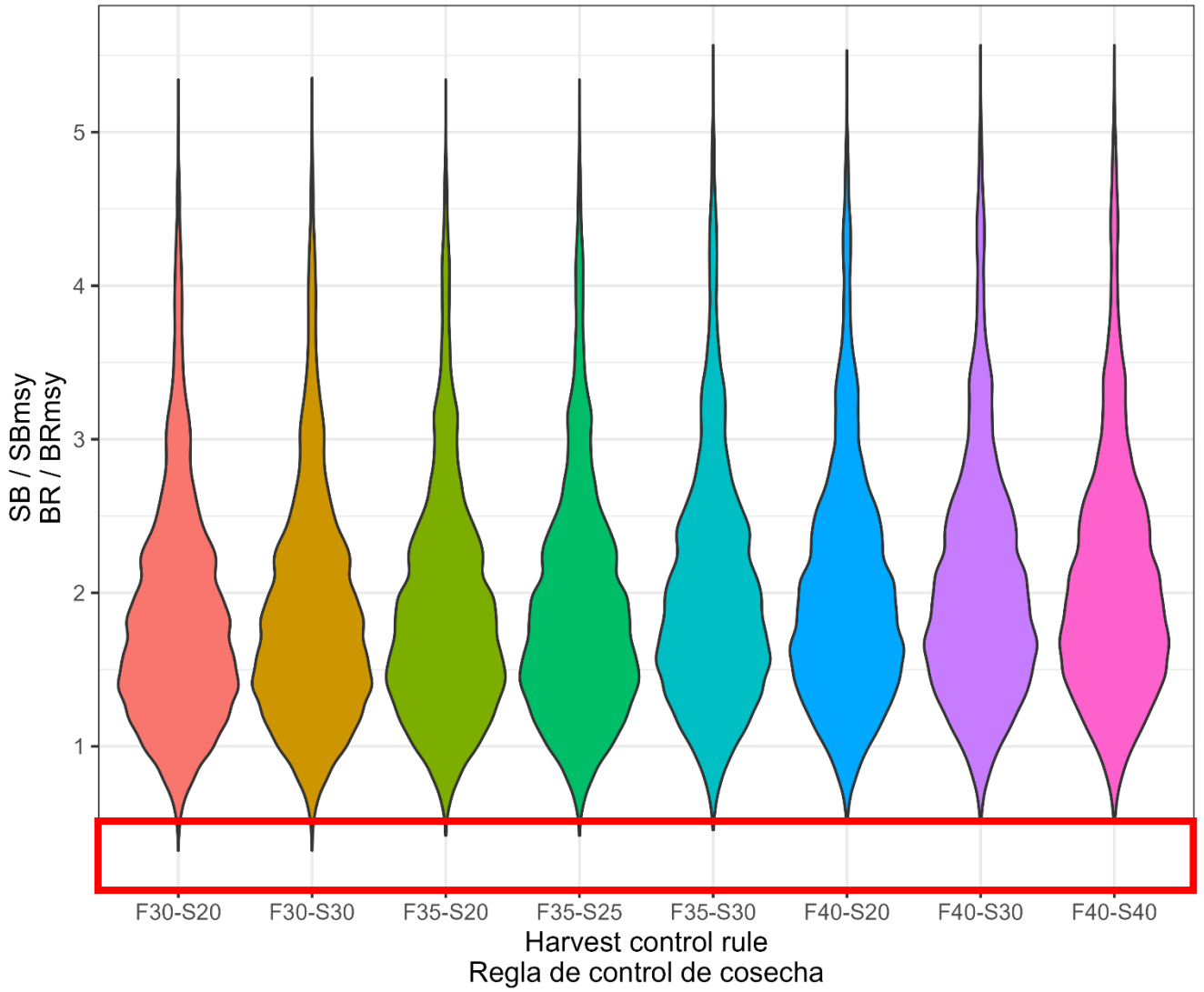
HCR	Prob (%) dSBR < 0.2	**Prob (%) SBR < 0.077**	Prob (%) $S/S_{MSY} < 0.5$
F30-S20	3.5	**0.1**	0.1
F30-S30	3.3	**0.1**	0.1
F35-S20	2.5	**0**	0
F35-S25	2.5	**0**	0
F35-S30	1.7	**0**	0
F40-S20	1.5	**0**	0
F40-S30	1.3	**0**	0
F40-S40	1.2	**0**	0



Performance indicators: safety

The probability that spawning biomass falls below 50% of the spawning biomass at MSY

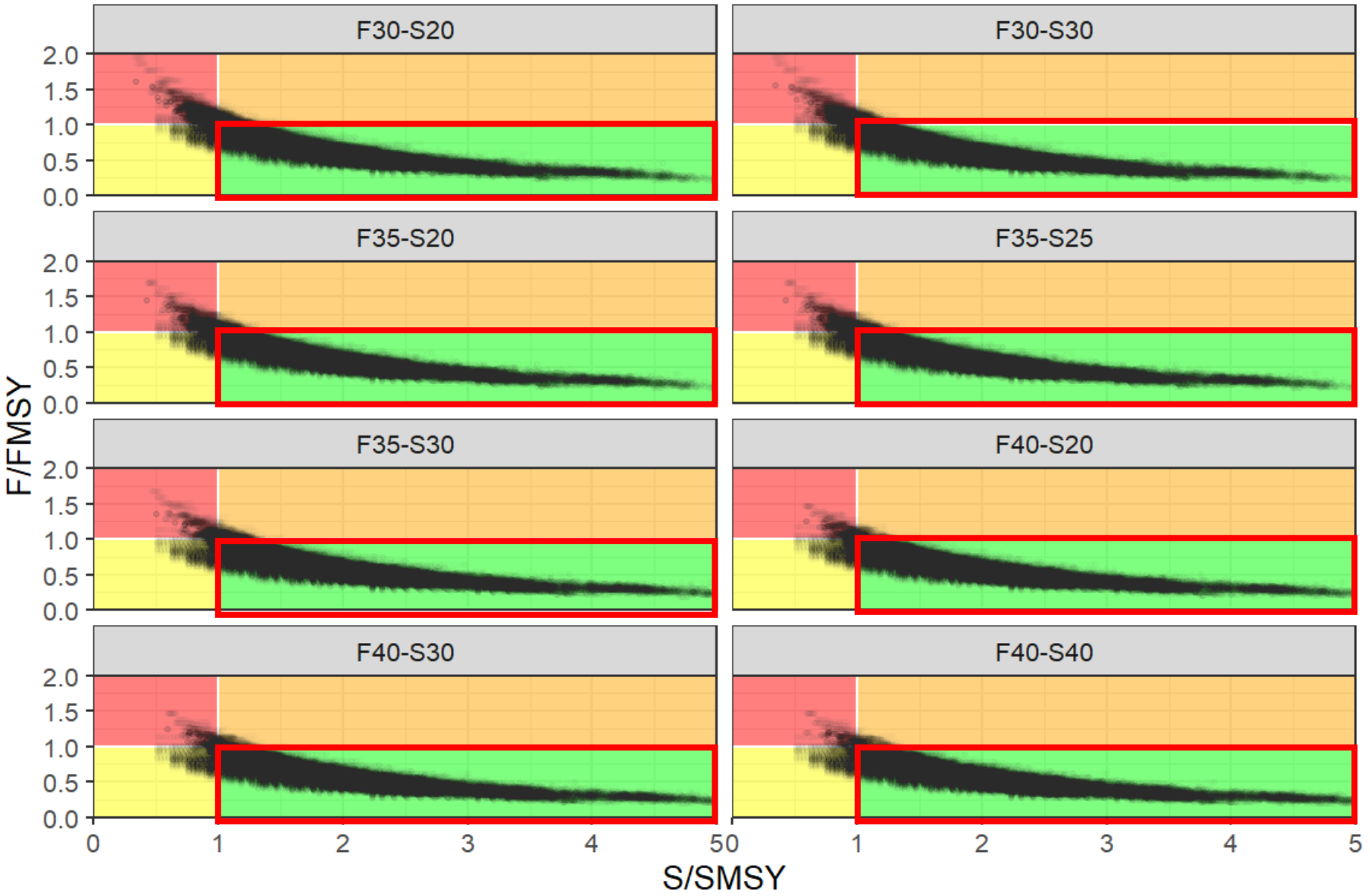
HCR	Prob (%) dSBR < 0.2	Prob (%) SBR < 0.077	**Prob (%) S/S_{MSY} < 0.5**
F30-S20	3.5	0.1	**0.1**
F30-S30	3.3	0.1	**0.1**
F35-S20	2.5	0	**0**
F35-S25	2.5	0	**0**
F35-S30	1.7	0	**0**
F40-S20	1.5	0	**0**
F40-S30	1.3	0	**0**
F40-S40	1.2	0	**0**



Performance indicators: status

The probability that the stock is in the green Kobe quadrant

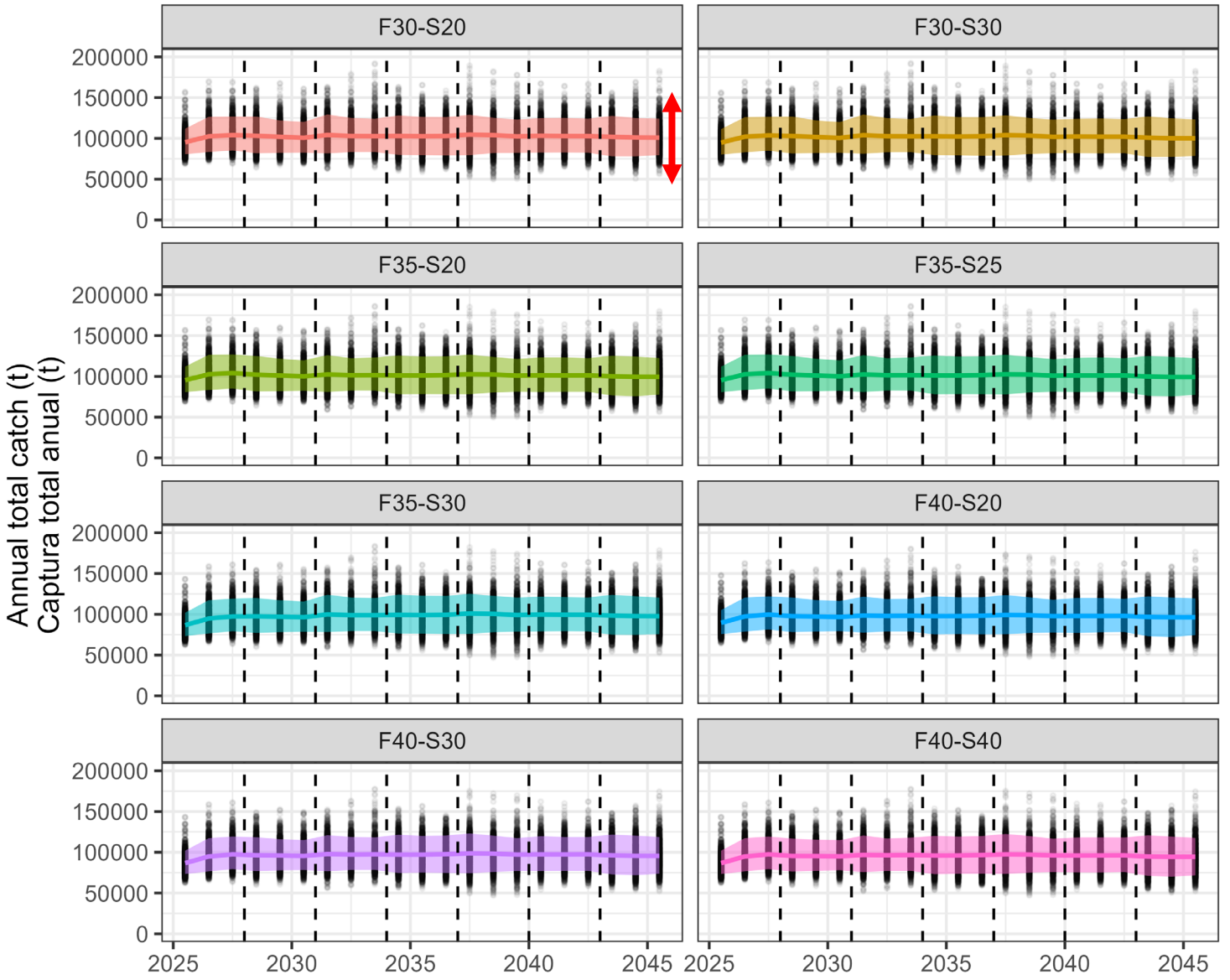
HCR	Prob (%) Kobe = green
F30-S20	89.6
F30-S30	90.0
F35-S20	91.6
F35-S25	91.6
F35-S30	94.0
F40-S20	94.6
F40-S30	95.2
F40-S40	95.5



Performance indicators: stability

Average annual variability in annual bigeye catch

HCR	**AAV (%) in catch**	Prob (%) change = 20
F30-S20	**7.3**	0.8
F30-S30	**7.3**	7.7
F35-S20	**7.3**	0.4
F35-S25	**7.3**	1.9
F35-S30	**7.2**	17.6
F40-S20	**7.2**	0.1
F40-S30	**7.2**	16.3
F40-S40	**7.3**	28.9



Performance indicators: stability

The probability that the closure will increase by 20 days

HCR	AAV (%) in catch	**Prob (%) change = 20**
F30-S20	7.3	**0.8**
F30-S30	7.3	**7.7**
F35-S20	7.3	**0.4**
F35-S25	7.3	**1.9**
F35-S30	7.2	**17.6**
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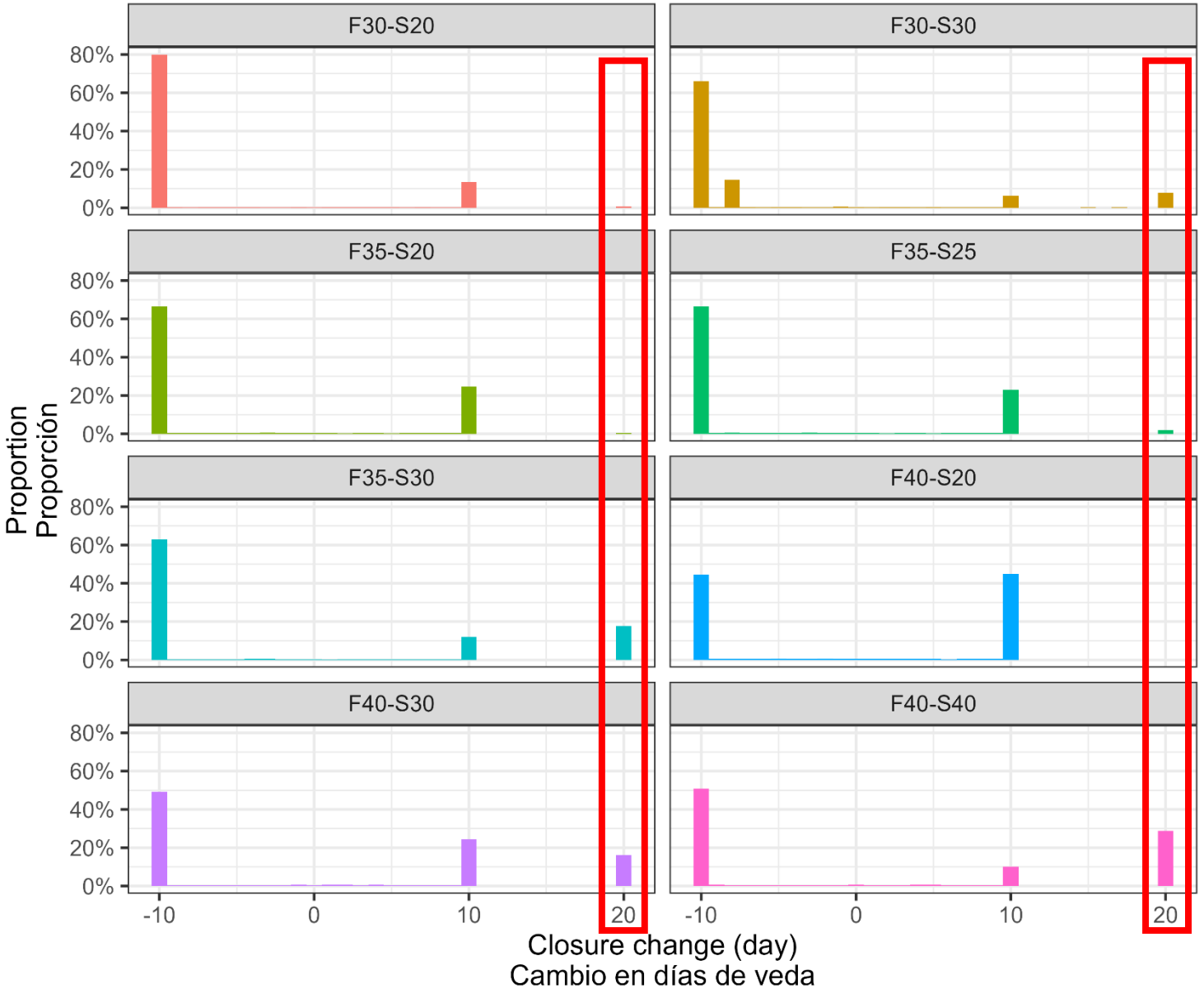
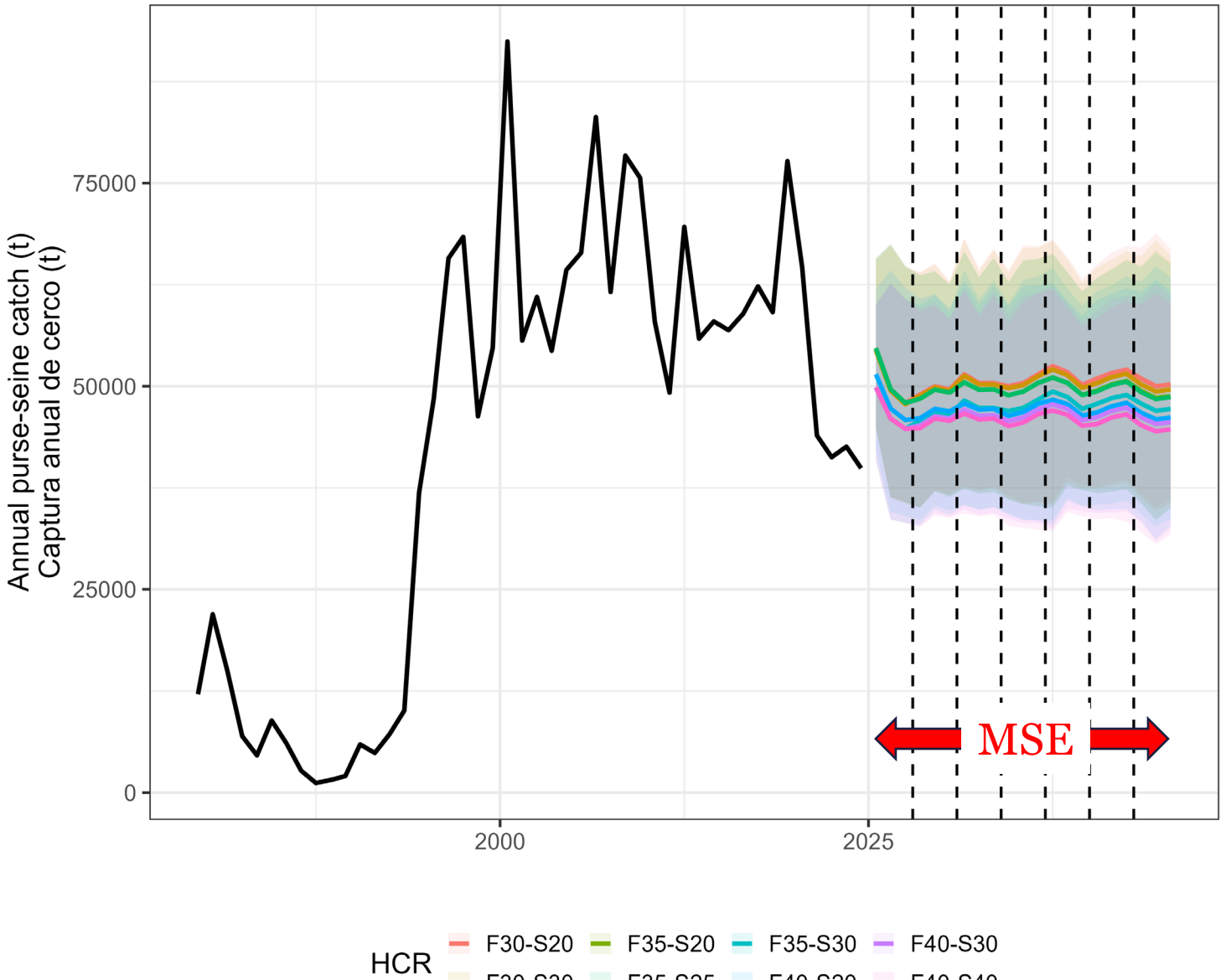


Performance indicators: yield

Average annual purse-seine catch

HCR	**Annual PS catch (mt)**	Annual LL catch (mt)
F30-S20	**50722**	51663
F30-S30	**50384**	51509
F35-S20	**49785**	51277
F35-S25	**49746**	51250
F35-S30	**47514**	50533
F40-S20	**47221**	50258
F40-S30	**46456**	49966
F40-S40	**45911**	49624



Performance indicators: yield

Average annual longline catch

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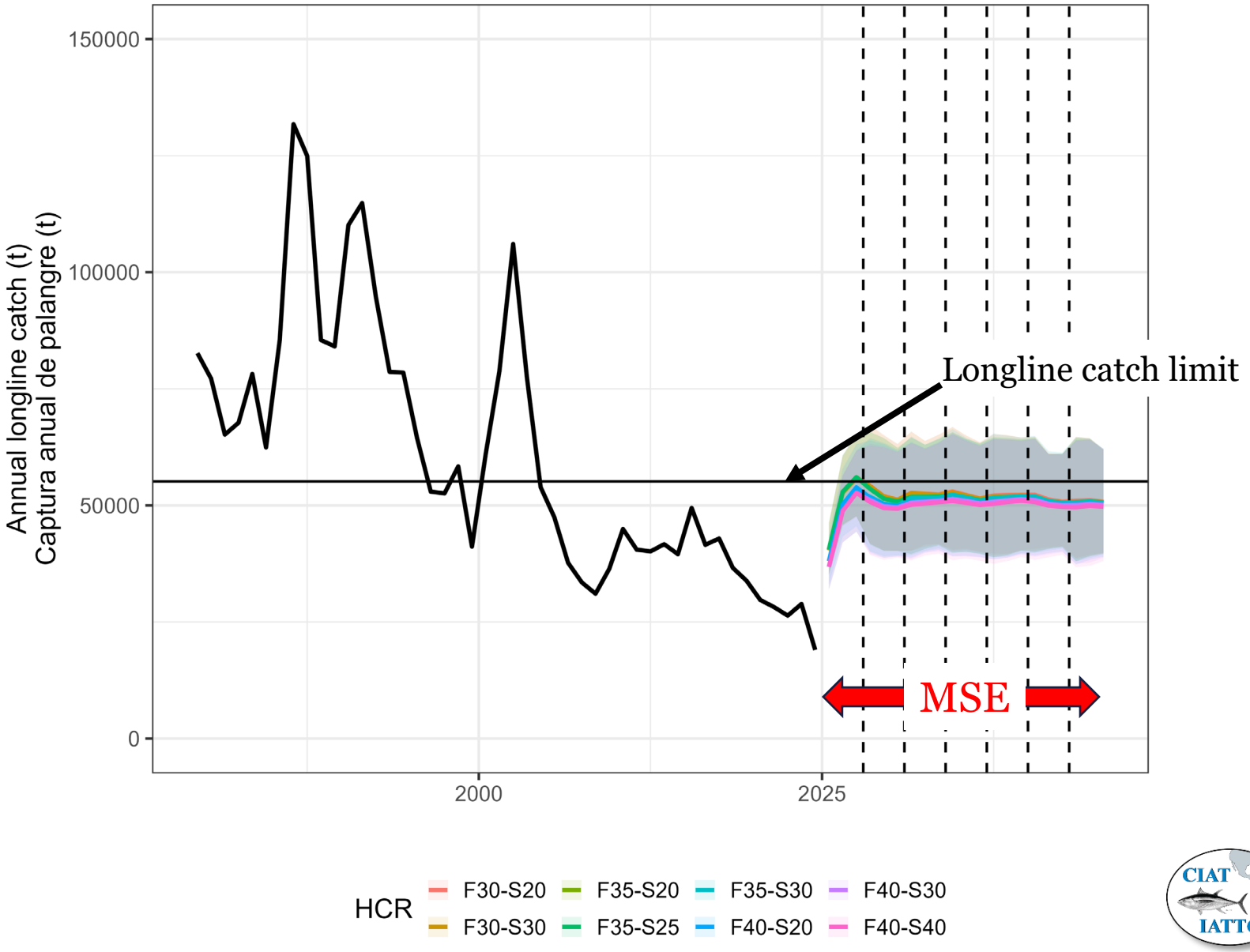
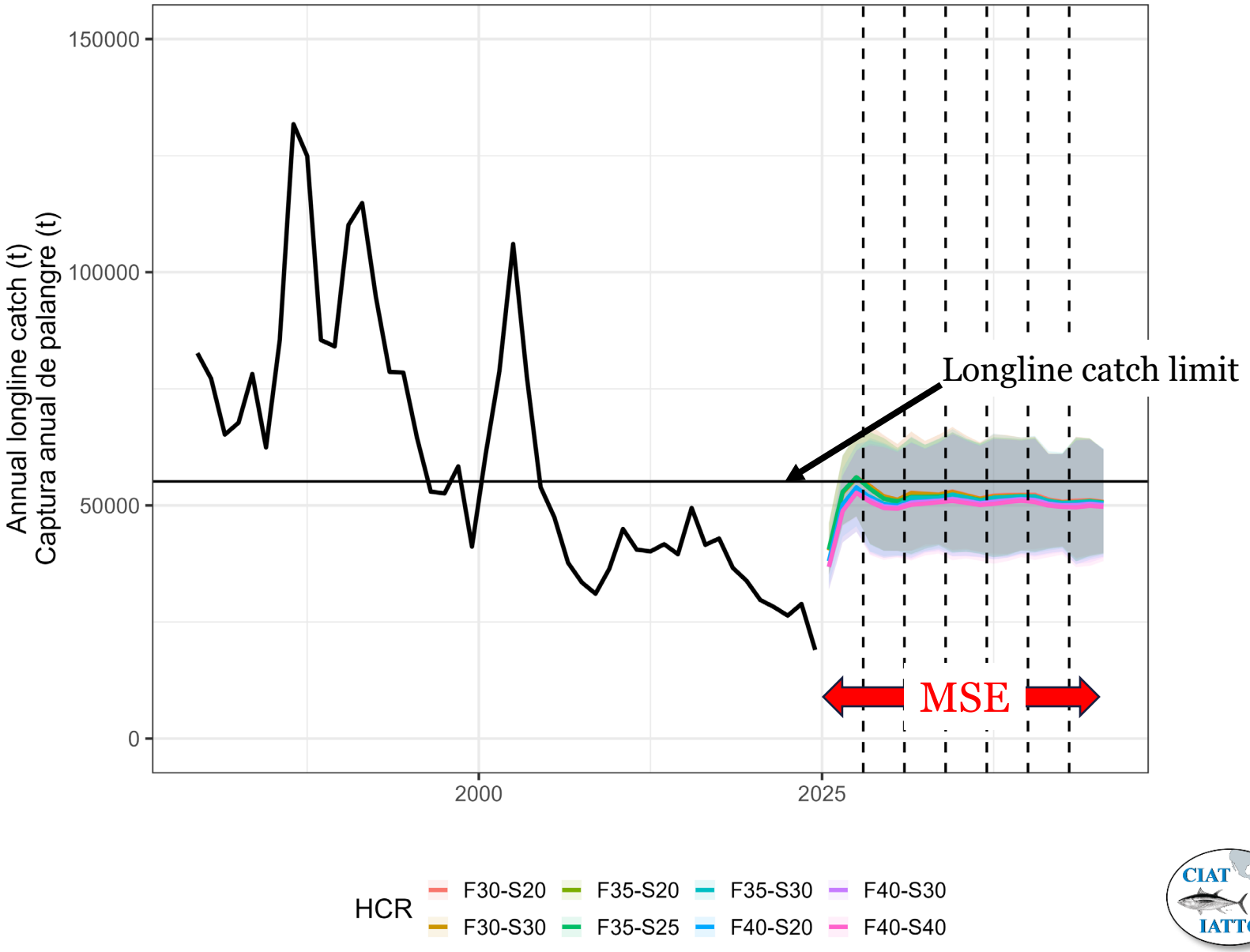


Performance indicators: yield

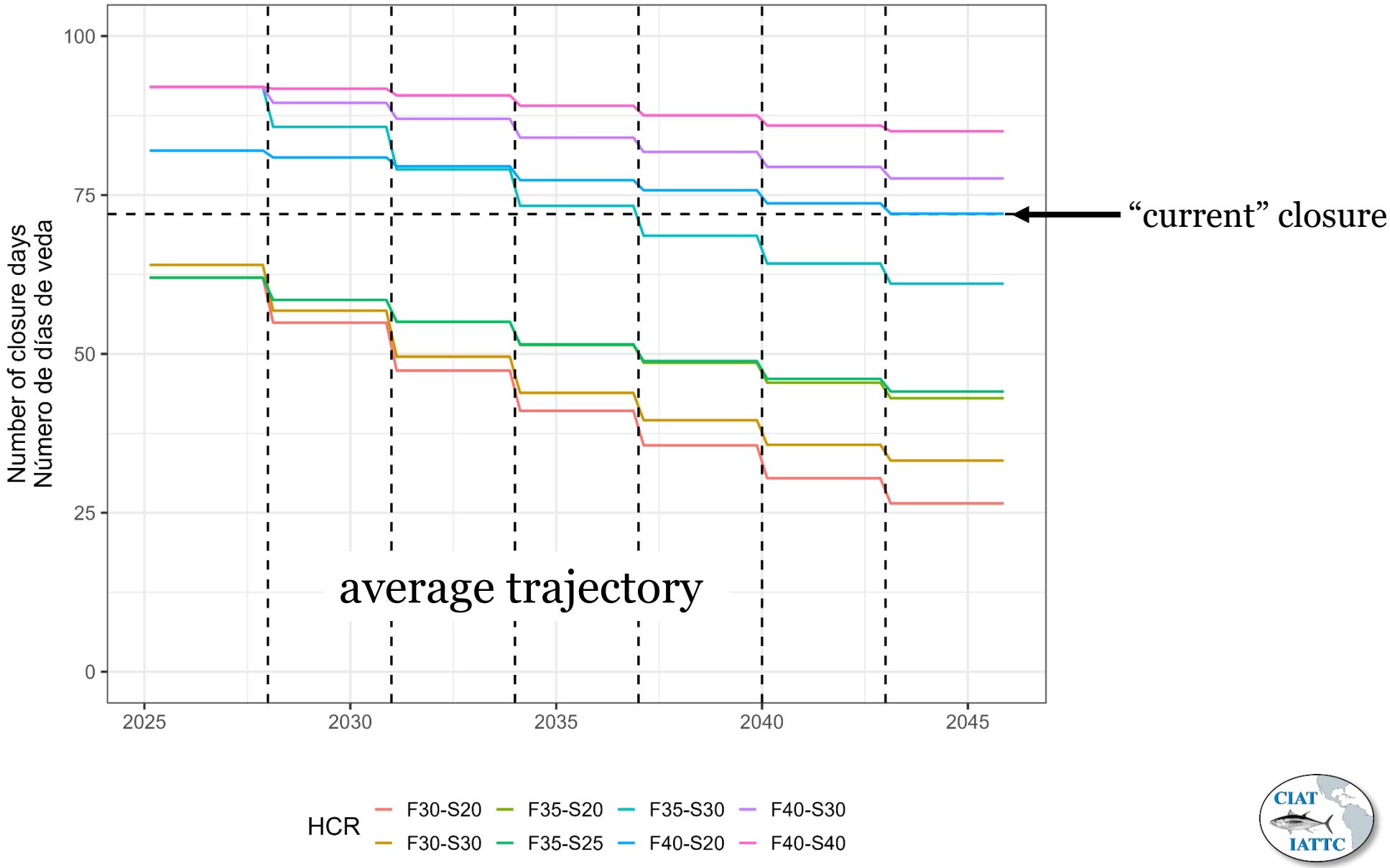
- The MSE cannot set a longline catch limit in simulations due to technical difficulties (unable to resolve in the near term)
- Simulations suggest that future longline catches could exceed the total limit in future years
- **The stock is expected to reach a more optimistic status than that simulated in the MSE**



Performance indicators: effort

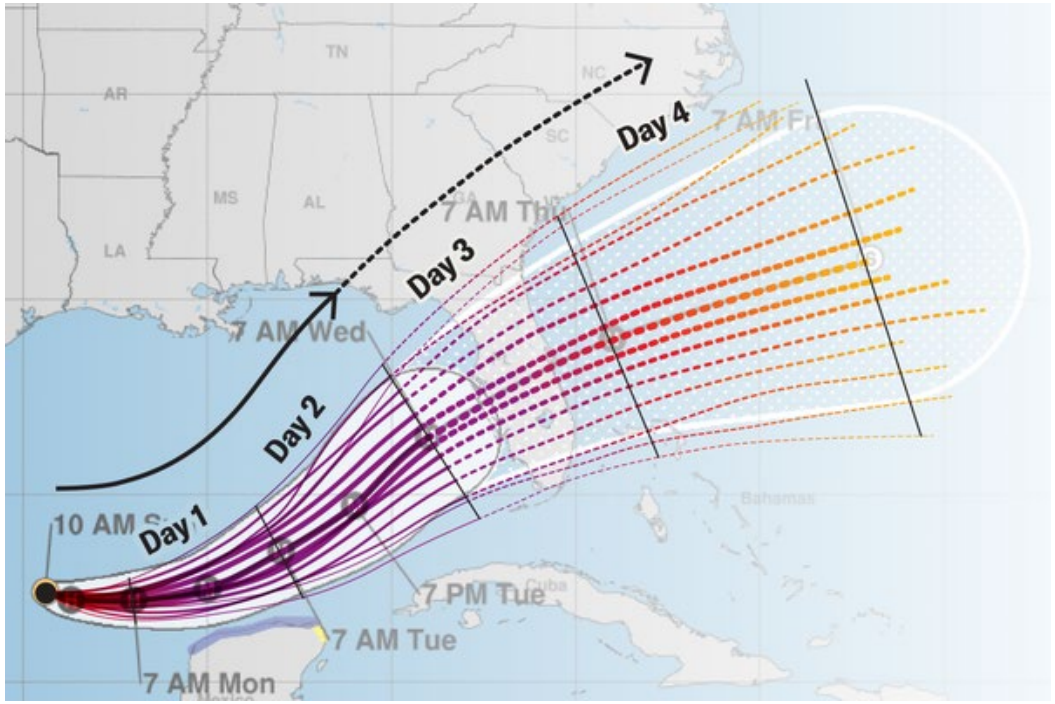
Average fishery closure

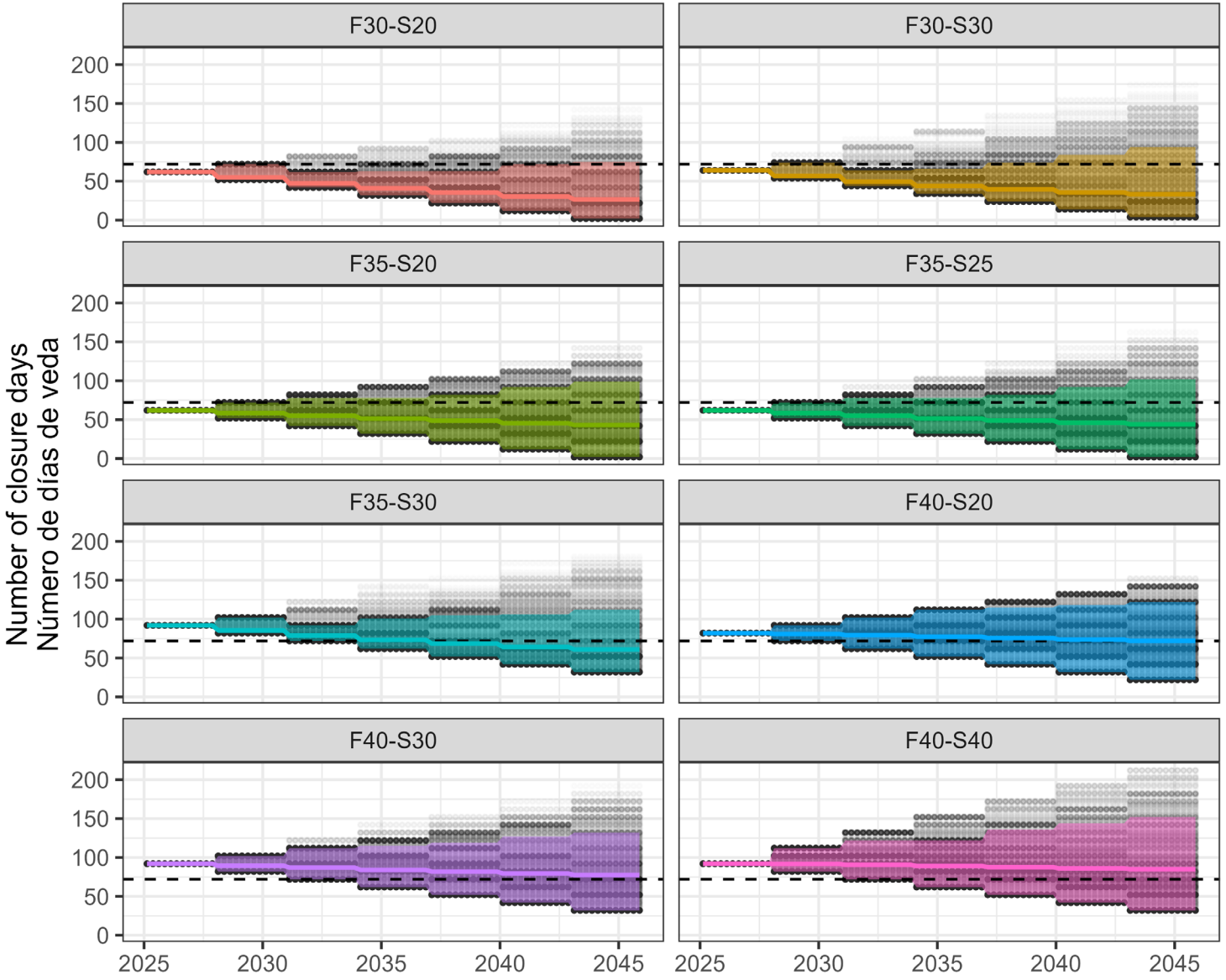
HCR	Average closure (day)
F30-S20	43
F30-S30	46
F35-S20	52
F35-S25	52
F35-S30	75
F40-S20	77
F40-S30	84
F40-S40	89



Performance indicators: effort

The further we project into the future, the more uncertain the projection becomes.

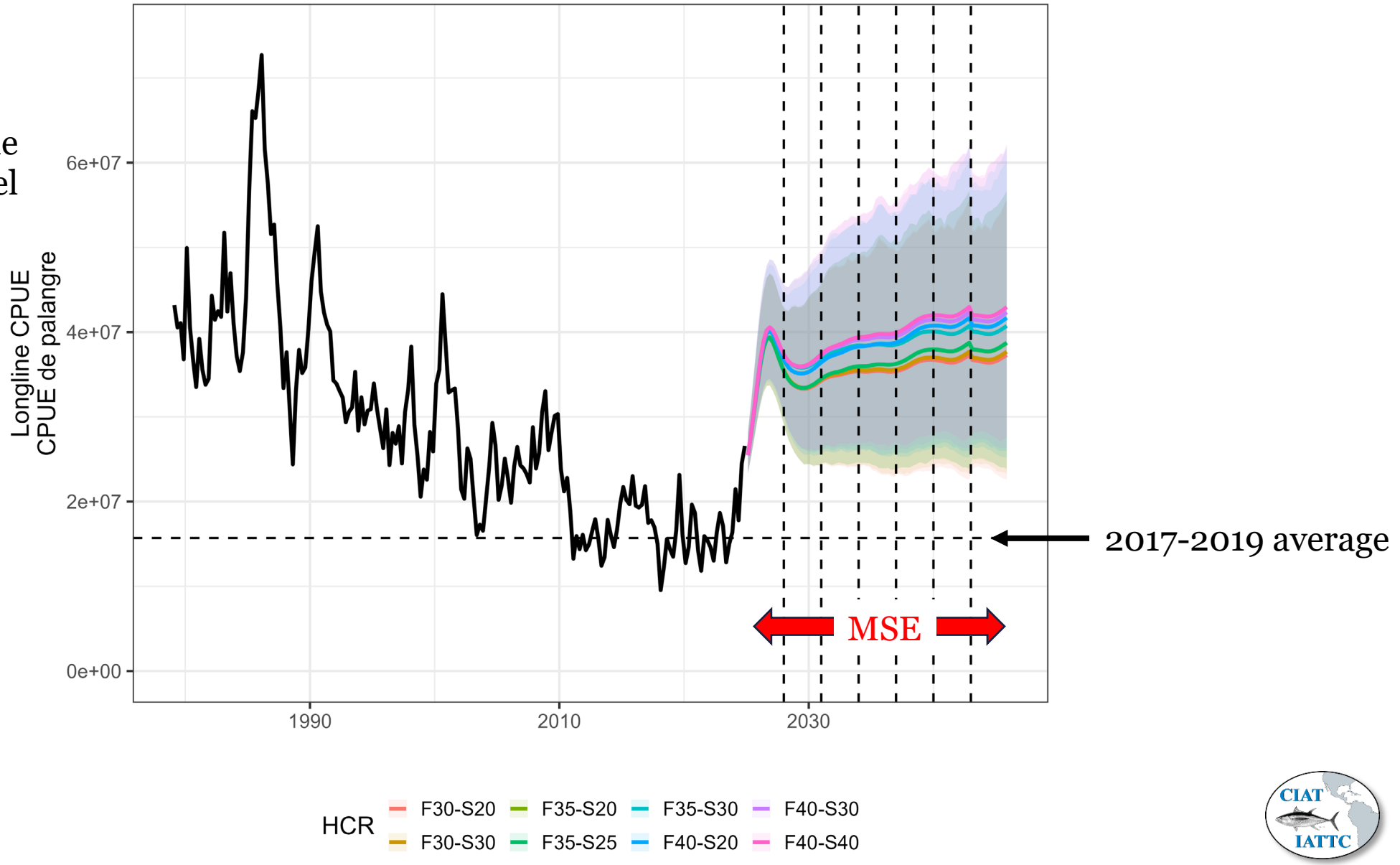




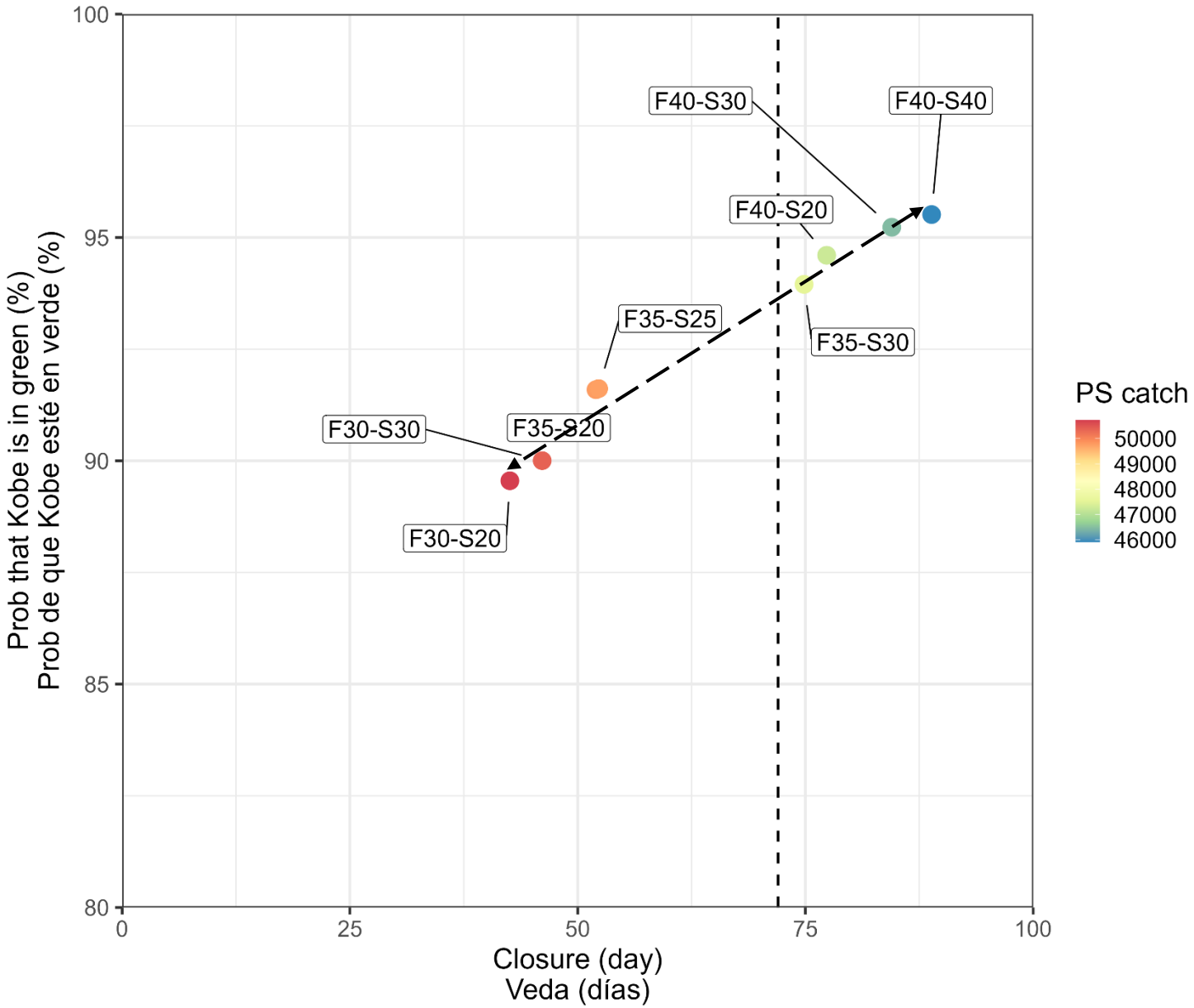
Performance indicators: abundance

The ratio of average longline CPUE to the 2017-2019 level

HCR	CPUE ratio
F30-S20	2.26
F30-S30	2.28
F35-S20	2.31
F35-S25	2.31
F35-S30	2.44
F40-S20	2.45
F40-S30	2.49
F40-S40	2.51



Trade-off: status vs. effort



Performance indicators: summary

Very low probability of breaching the limit reference points

Small contrast

HCR	Prob dSBR < 0.2	Prob SBR < 0.077	Prob S/S_{MSY}<0.5	Prob Kobe = green	AAV in catch	Prob change = 20	Annual PS catch	Annual LL catch	Average closure	CPUE ratio
F30-S20	3.5	0.1	0.1	89.6	7.3	0.8	50722	51663	43	2.26
F30-S30	3.3	0.1	0.1	90.0	7.3	7.7	50384	51509	46	2.28
F35-S20	2.5	0	0	91.6	7.3	0.4	49785	51277	52	2.31
F35-S25	2.5	0	0	91.6	7.3	1.9	49746	51250	52	2.31
F35-S30	1.7	0	0	94.0	7.2	17.6	47514	50533	75	2.44
F40-S20	1.5	0	0	94.6	7.2	0.1	47221	50258	77	2.45
F40-S30	1.3	0	0	95.2	7.2	16.3	46456	49966	84	2.49
F40-S40	1.2	0	0	95.5	7.3	28.9	45911	49624	89	2.51

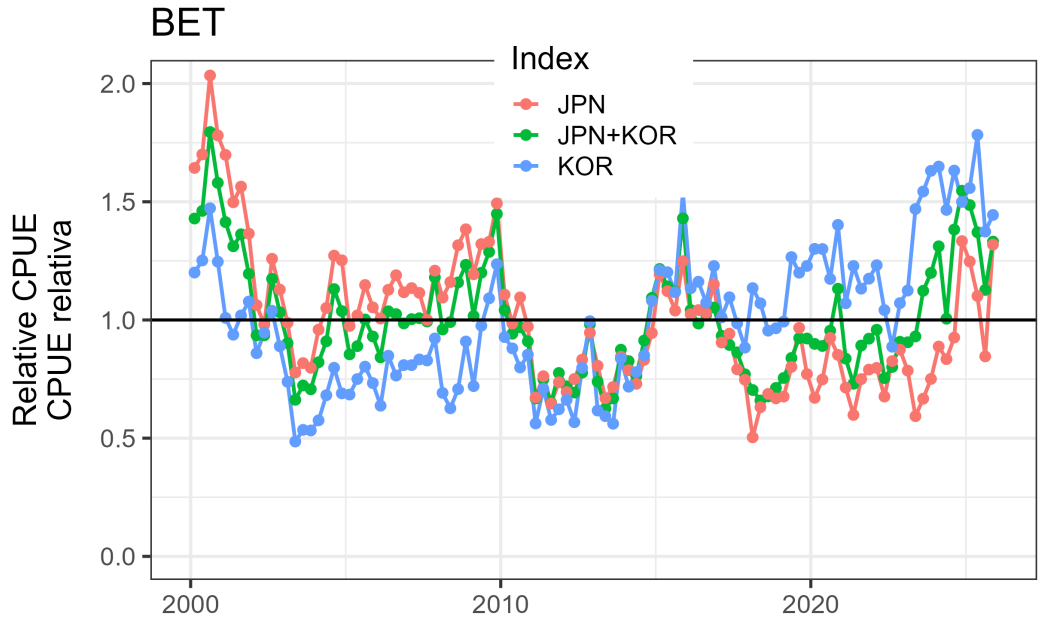
Take-home message

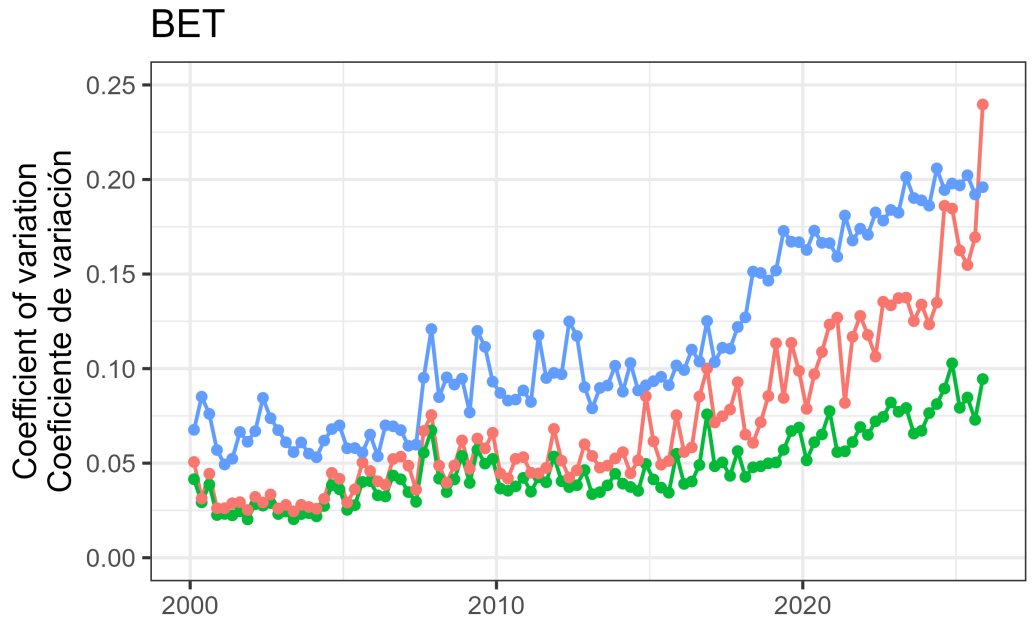
- MSE was conducted for bigeye in the EPO
- Eight candidate HCRs have been tested
- Three HCRs were identified that achieve:
  - Safety
  - Status
  - Decreased purse-seine closure duration
  - Increased longline yield
  - Stability
- The three HCRs are:
  - F30-S20
  - F35-S20
  - F35-S25


Questions

Background

- The longline index in the current stock assessment and MSE is based on Japanese longline CPUE
- It shows increasingly larger CV in recent years due to reduced spatial coverage and fishing effort (# of sets)





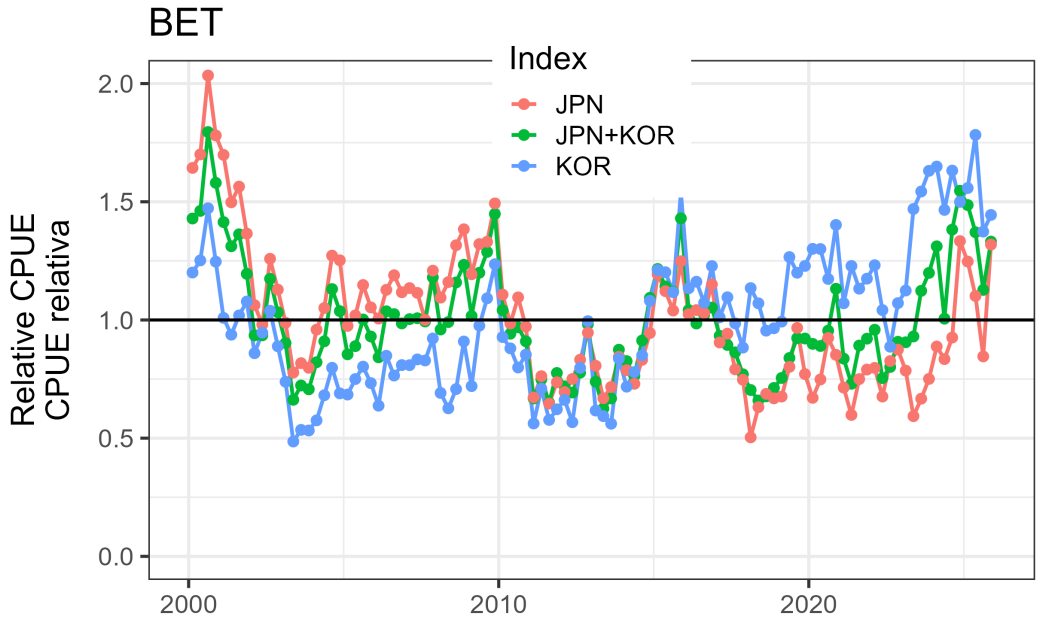
Background

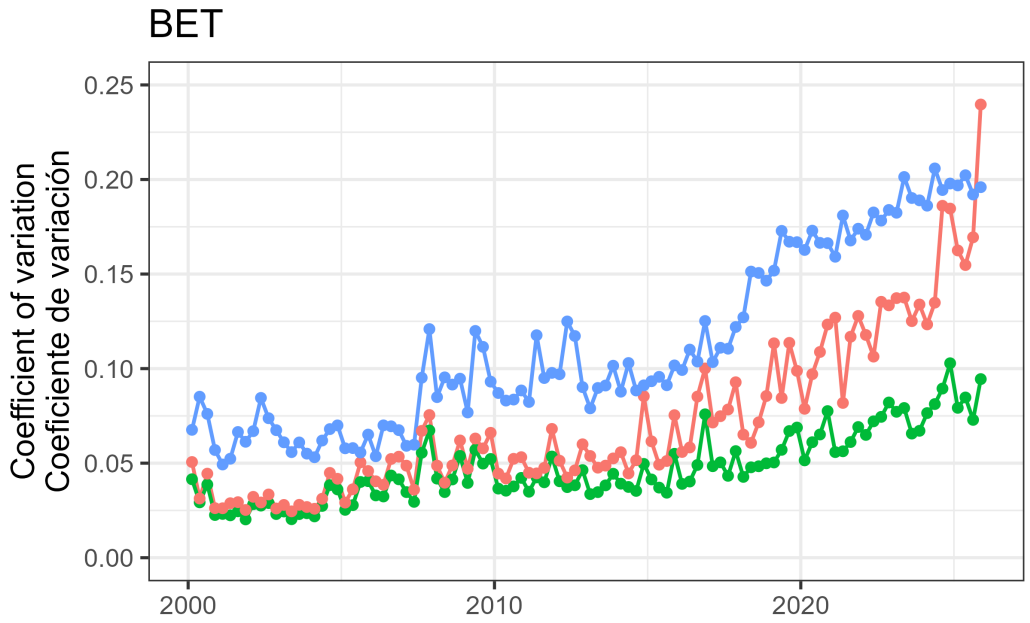
Uncertainty:

- Time-varying CV is included in the current stock assessment and MSE to account for increasingly uncertain index

Bias:

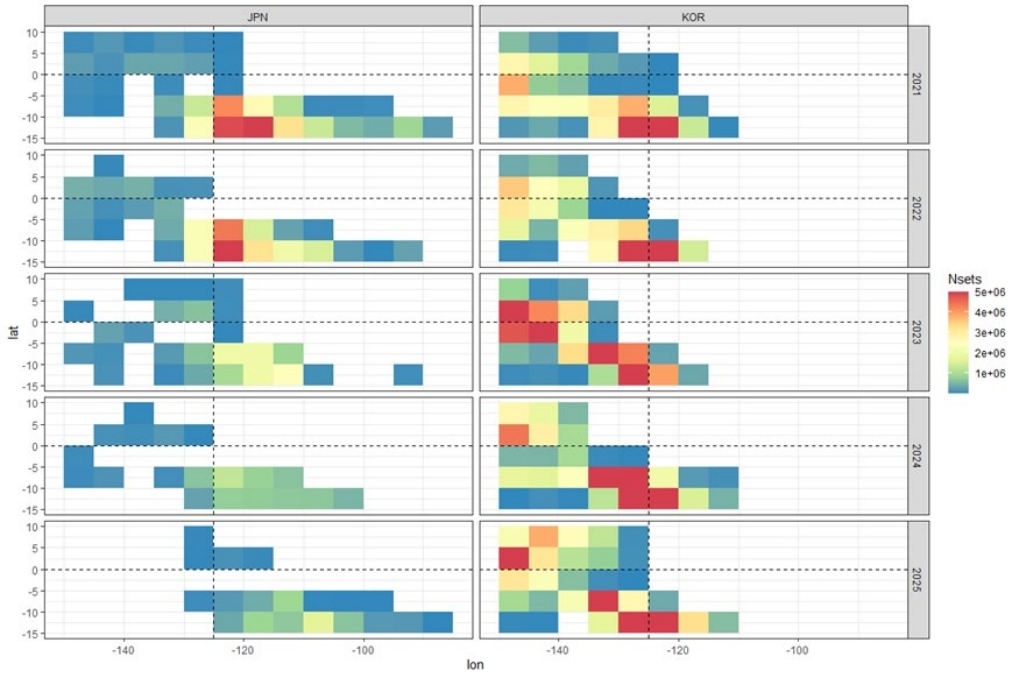
- The index accounts for increased catchability due to vessel turnover in the standardization process and an additional catchability increase as an axis of uncertainty in the risk analysis and MSE

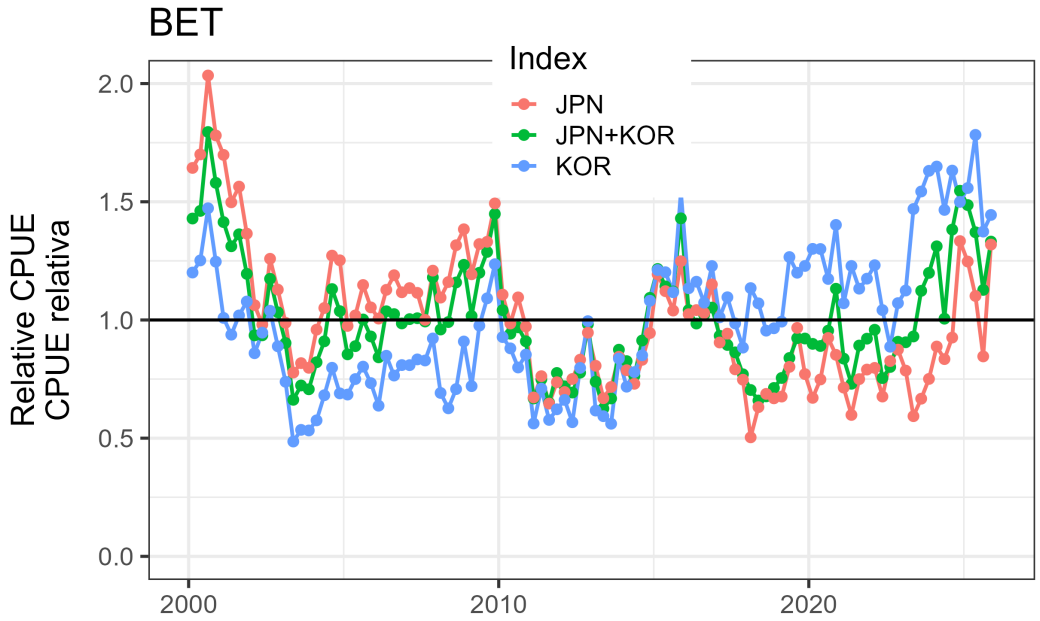


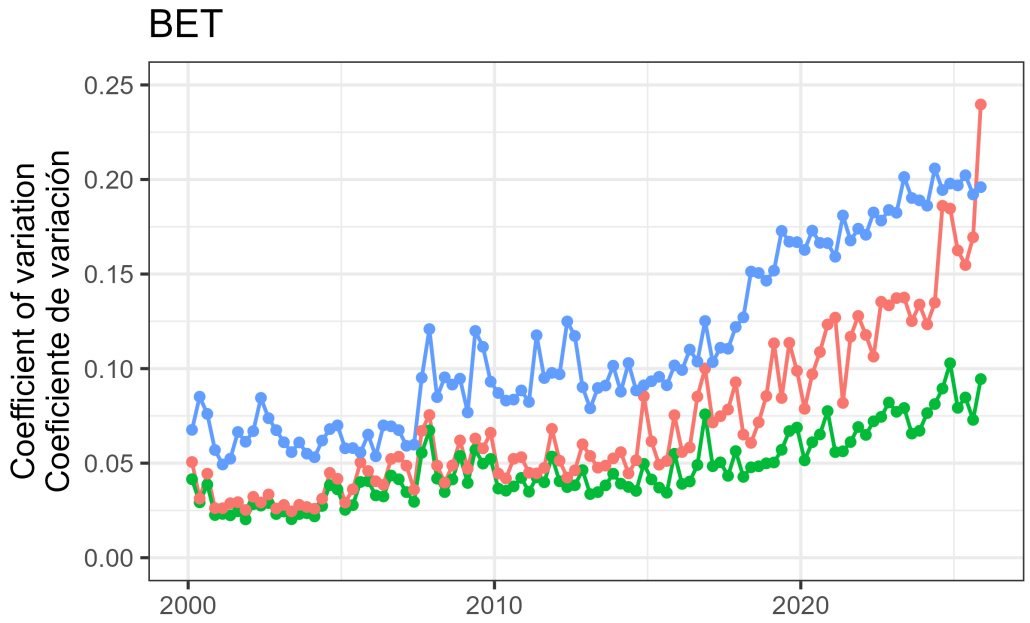


Background

- The Korean longline fleet operates in different parts of the EPO, so the joint index has significantly reduced CV

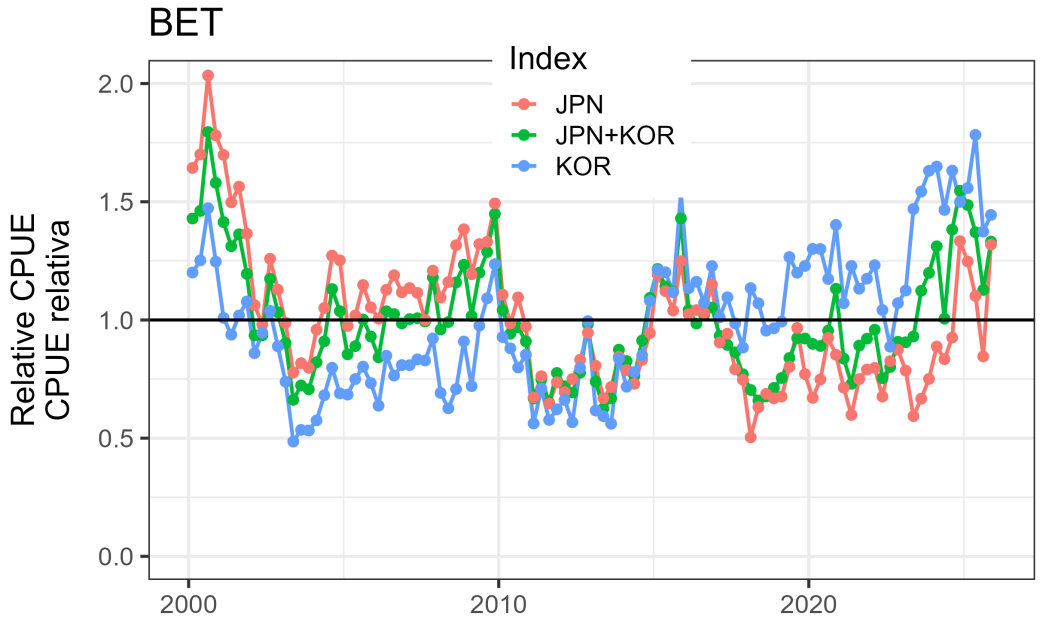


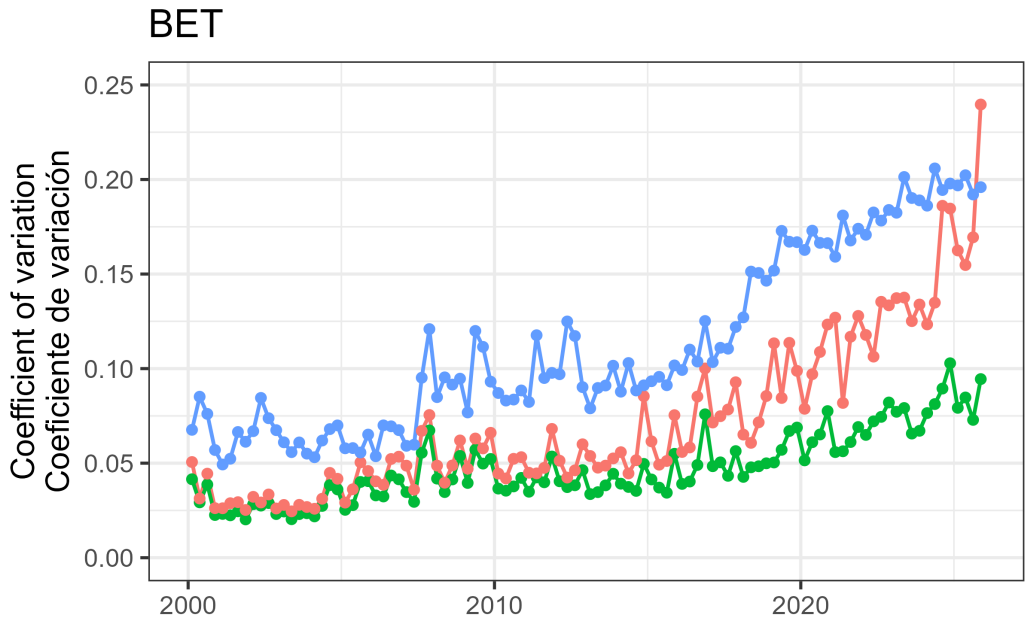




Background

- The Korean longline fleet operates in different parts of the EPO, so the joint index has significantly reduced CV
- The joint index shows a notably more optimistic trend, suggesting a more optimistic population trajectory if the Japanese index is replaced by the joint index





Robustness test

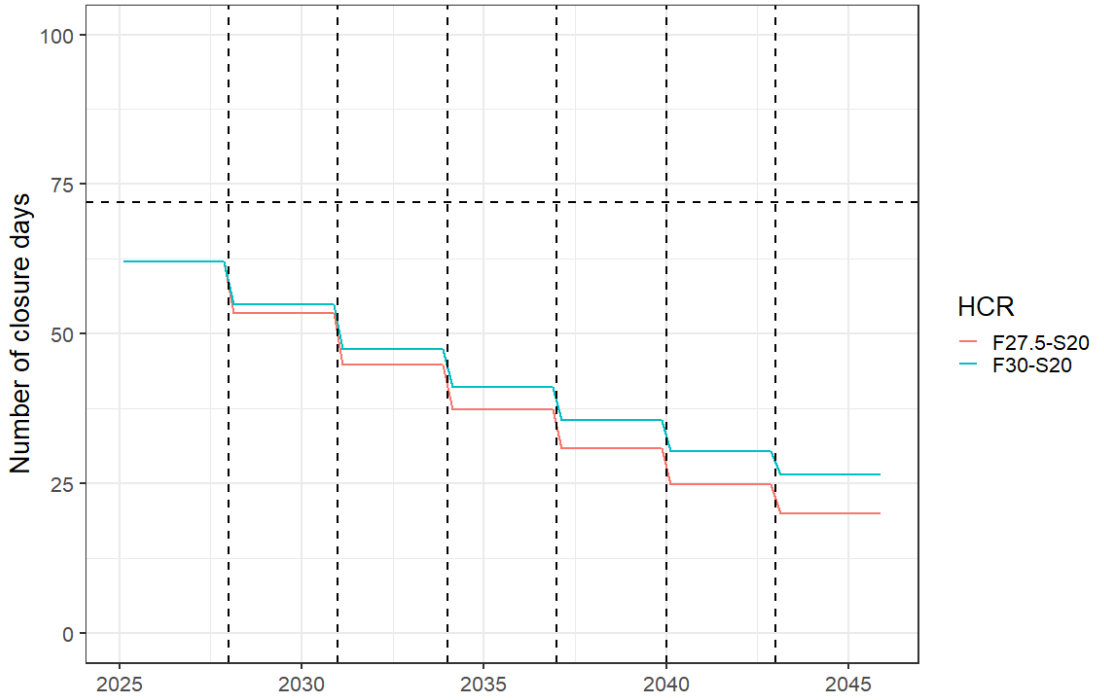
- Evaluate the performance of the candidate HCRs under a sustained 25% reduction in recruitment regime beginning in 2025.
- This scenario is intended to assess HCR behavior under unfavorable environmental conditions that substantially reduce stock productivity.
- Except for the imposed regime shift in recruitment, all simulation specifications for the robustness test were identical to those used in the base-case MSE.
- Due to time constraints, the robustness test was conducted only for the least conservative candidate HCR, F30–S20, which is expected to be most vulnerable to declines in recruitment.

Robustness test

- The least conservative HCR, F30-S20, is robust to a downward regime shift in recruitment:
  - Less than 1% probabilities in breaching the two hard limit reference points
  - Less than 5% probability in breaching the soft limit reference point
  - More than 85% probability that the stock is in the green quadrant of the Kobe plot

R0	Prob dSBR > 0.2	Prob SBR > 0.077	Prob S > $0.5S_{MSY}$	Prob Kobe = green	AAV in catch	Prob change = 20	Annual PS catch	Annual LL catch	Fishery closure	CPUE ratio
75%	**95.4**	**99.0**	**99.8**	**88.5**	**7.2**	**1.5**	**38646**	**41096**	**38**	**1.76**
100%	96.5	99.9	99.9	89.6	7.3	0.8	50722	51663	43	2.26

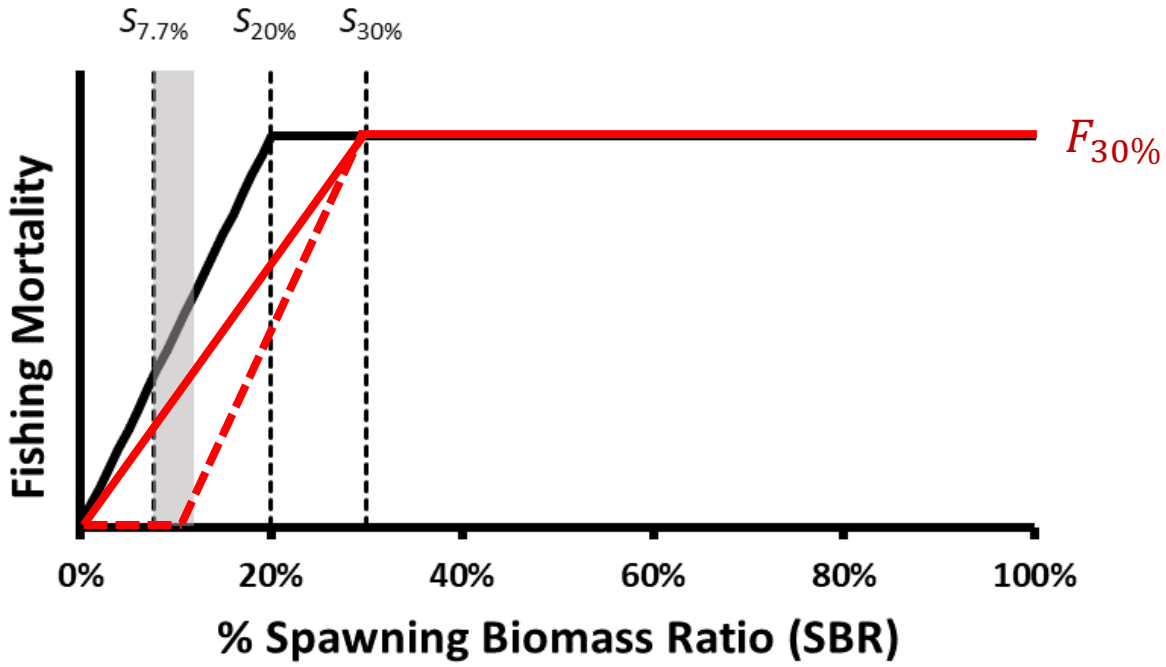
F27.5-S20



HCR	Prob dSBR > 0.2	Prob SBR > 0.077	Prob S > $0.5S_{MSY}$	Prob Kobe = green	AAV in catch	Prob change = 20	Annual PS catch	Annual LL catch	Fishery closure	CPUE ratio
F27.5-S20	96.1	99.8	99.9	88.8	7.3	1.1	51072	51797	39	2.25
F30-S20	96.5	99.9	99.9	89.6	7.3	0.8	50722	51663	43	2.26

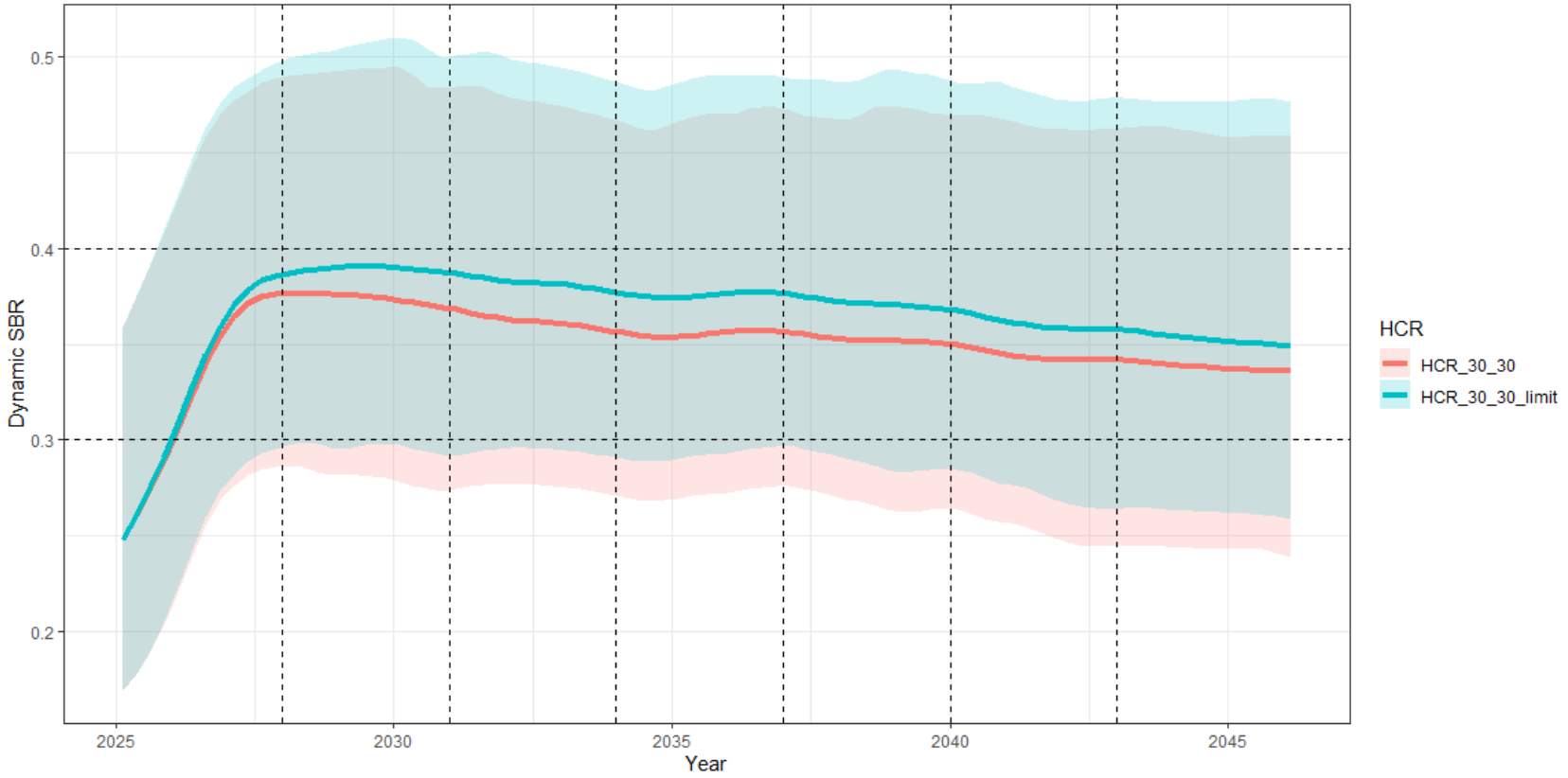
Impact of considering a second control point to the HCR

A second control point of 50%S_{MSY} (=0.1S_0) is considered in the HCR
Fishing mortality decreases linearly between the two control points, reaching 0 when the second point is breached



Impact of considering a second control point to the HCR

Considering a second control point of 50%SMSY in the HCR leads to more conservative management actions

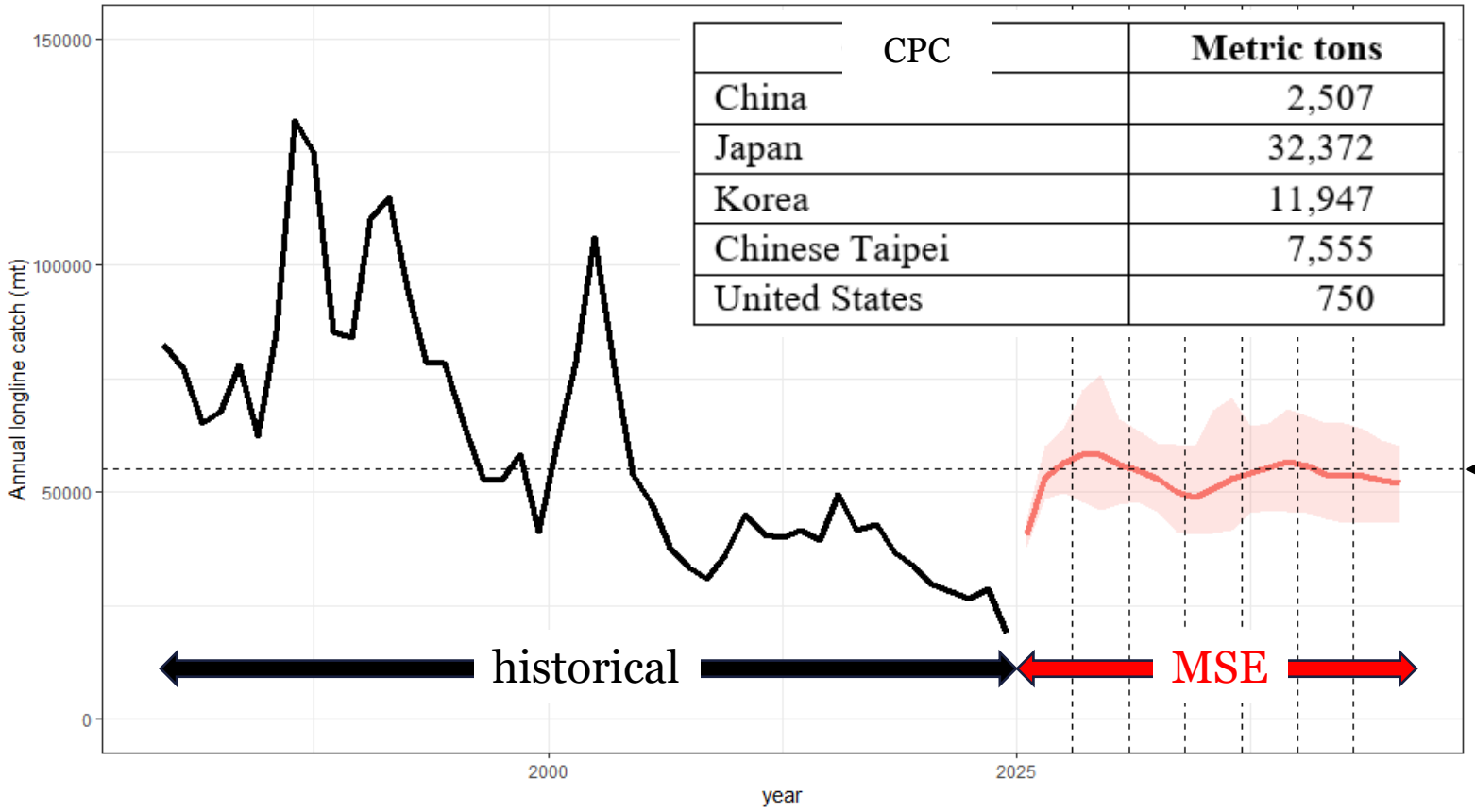


Discussion: adding another control point to the HCR

- All eight HCRs have a zero probability of breaching the two hard limit reference points
- If an asymmetric cap on closure changes (10/20-day cap) is used to enable rapid responses to depletion before breaching limit reference points, explicit inclusion of a second control point in the HCR may be unnecessary
- Incorporating a second control point increases the number of HCR parameters, further complicating negotiations surrounding the harvest strategy for bigeye tuna in the EPO
- Recommend do not explicitly including a second control point in the HCR unless the full results for the chosen HCR suggest that the probability of breaching the two hard limit reference points is >1%

Additional performance indicators - longline catch

For the stock under the staff HCR:
longline catch is projected to be close to the total limit (55,131 mt)



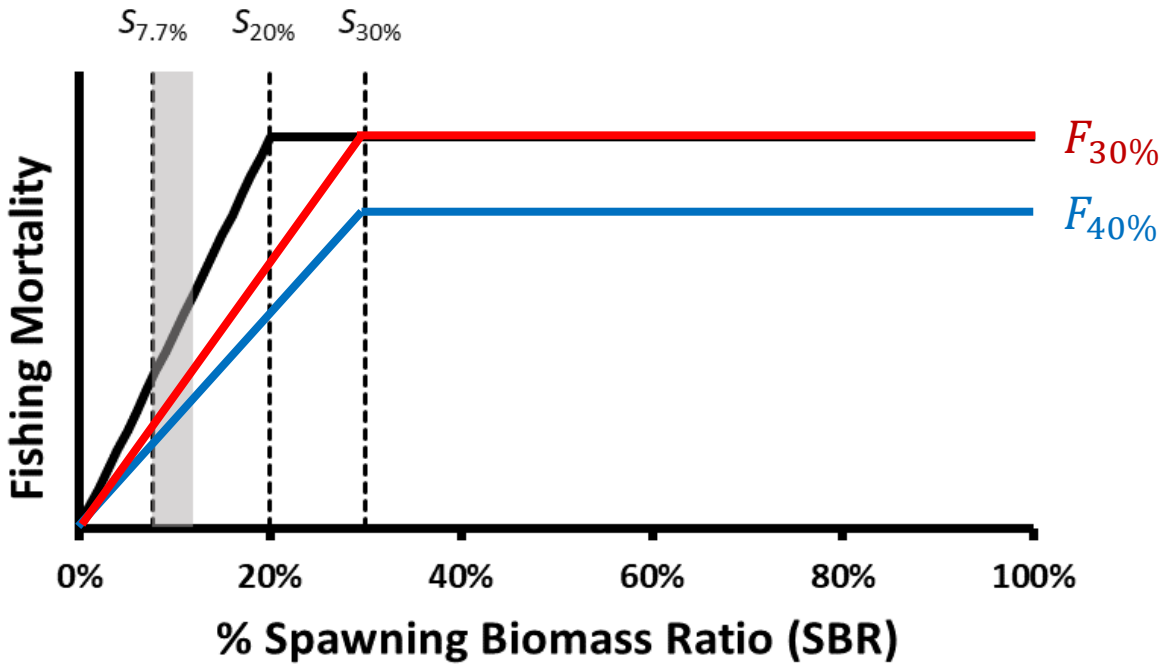
CPC	Metric tons
China	2,507
Japan	32,372
Korea	11,947
Chinese Taipei	7,555
United States	750

Resolution C-21-04

Total longline limit

Evaluate the performance of some HCRs

The MSEWG proposes to remove the 10-day cap for the increase in fishery closure when the stock is estimated to be below the control point, allowing for rapid response to depletion

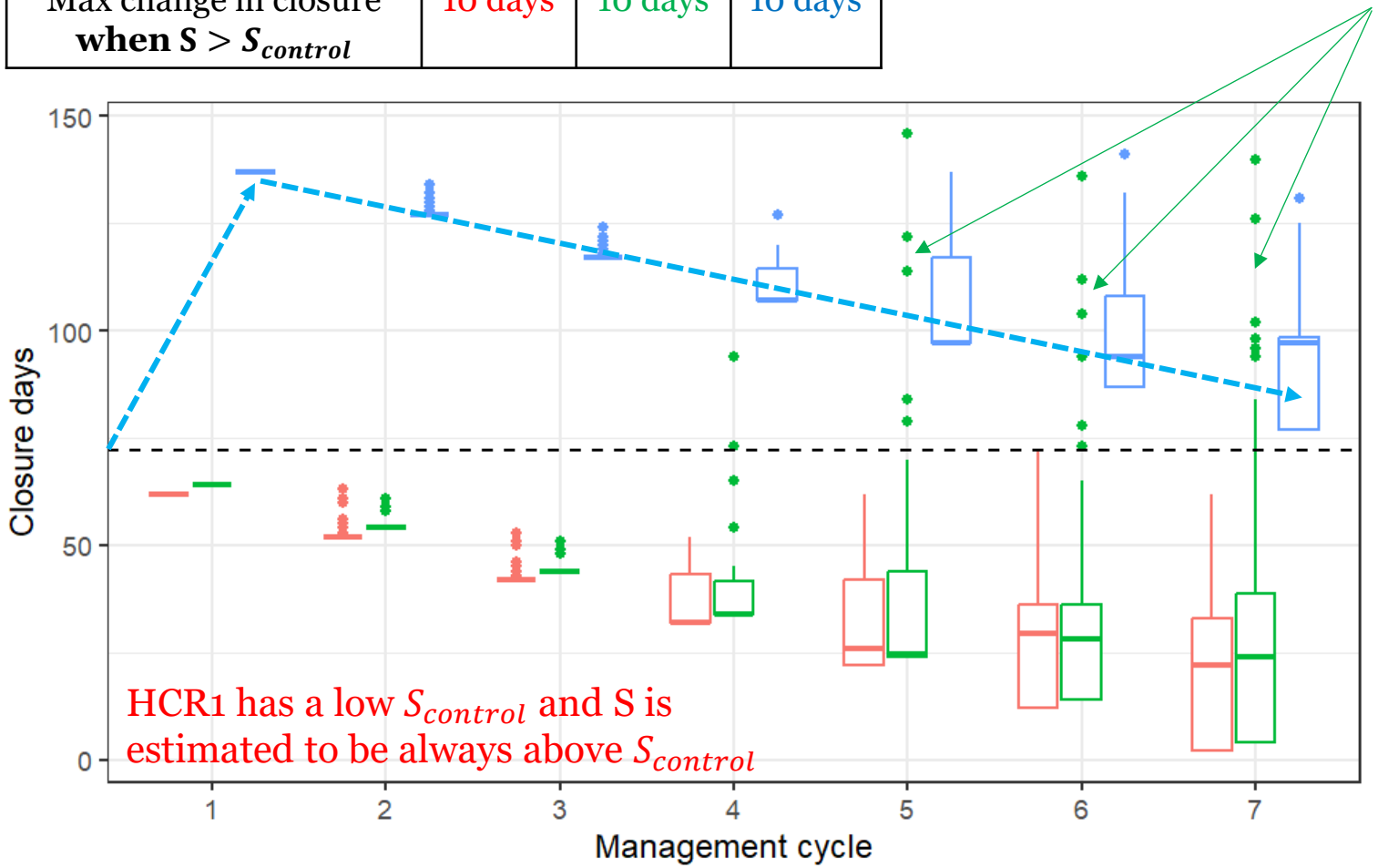


Component	HCR1	HCR2	HCR3
F_{max}	$F_{30\%}$	$F_{40\%}$	$F_{30\%}$
$S_{control}$	$S_{20\%}$	$S_{30\%}$	$S_{30\%}$
Max change in closure **when S > $S_{control}$**	10 days	10 days	10 days

Evaluate the performance of some HCRs

Component	HCR1	HCR2	HCR3
F_{max}	$F_{30\%}$	$F_{30\%}$	$F_{40\%}$
$S_{control}$	$S_{20\%}$	$S_{30\%}$	$S_{30\%}$
Max change in closure **when S > $S_{control}$**	10 days	10 days	10 days

HCR2 has same $S_{control}$ and S_{target}; occasionally leading to some extreme closures



HCR1 has a low $S_{control}$ and S is estimated to be always above $S_{control}$

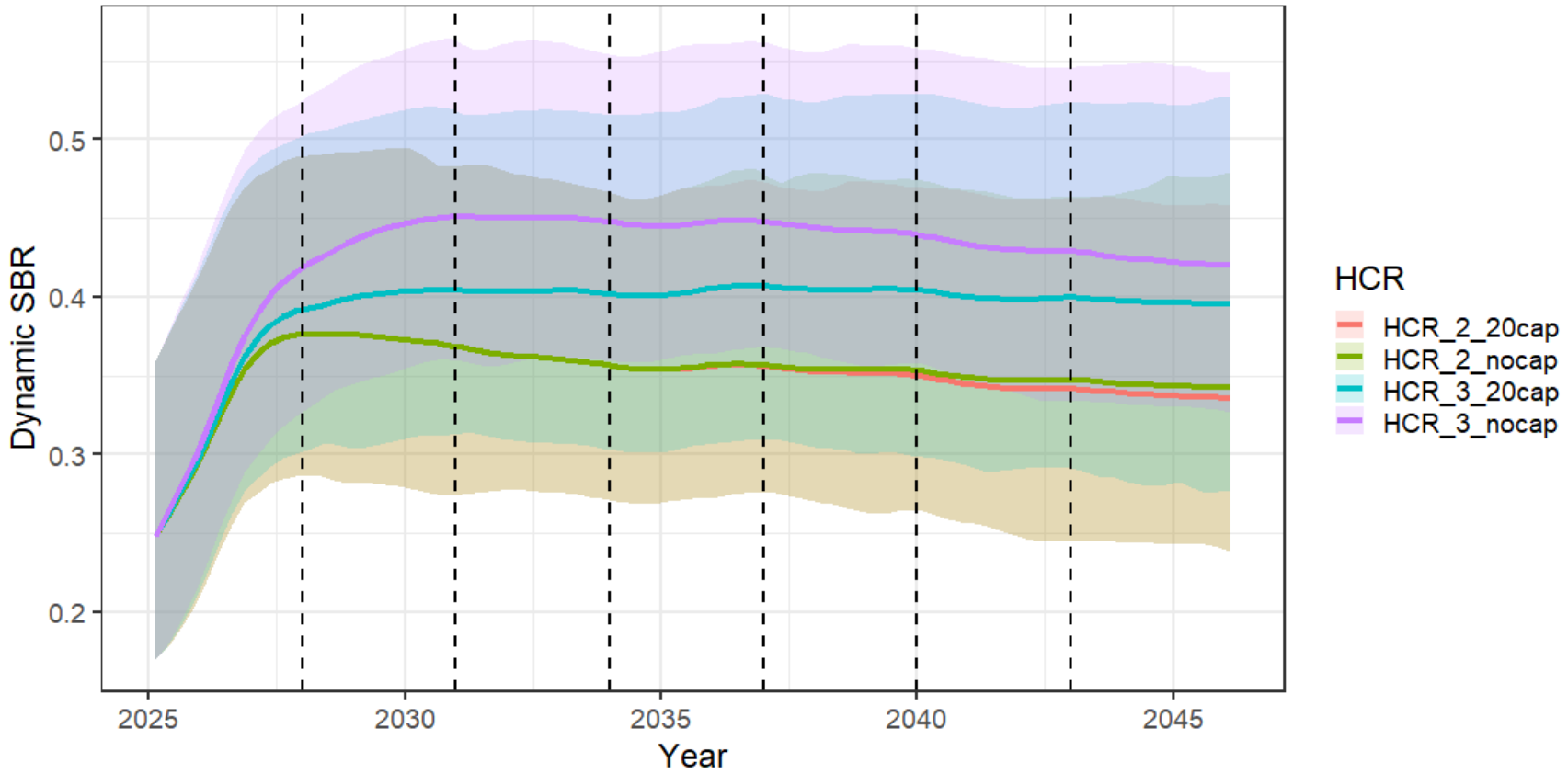
HCR3 has a high $S_{control}$ and even higher S_{target}; the stock is rebuilding from a low SBR (0.25), leading to a large initial closure

Evaluate the performance of some HCRs

- Removing the 10-day cap when $S<S_{control}$ intends to impose rapid response to depletion but leads to undesirable outcomes:
  - Instability (HCR2): large increases in closure day are occasionally observed
  - Inflexibility (HCR3): management action can get "stuck" in the excessively conservative zone when S rebuilds above $S_{control}$ due to the 10-day cap when $S>S_{control}$
- A 20-day cap instead of no cap when $S<S_{control}$ is tested for HCR2 and HCR3

Evaluate the performance of some HCRs

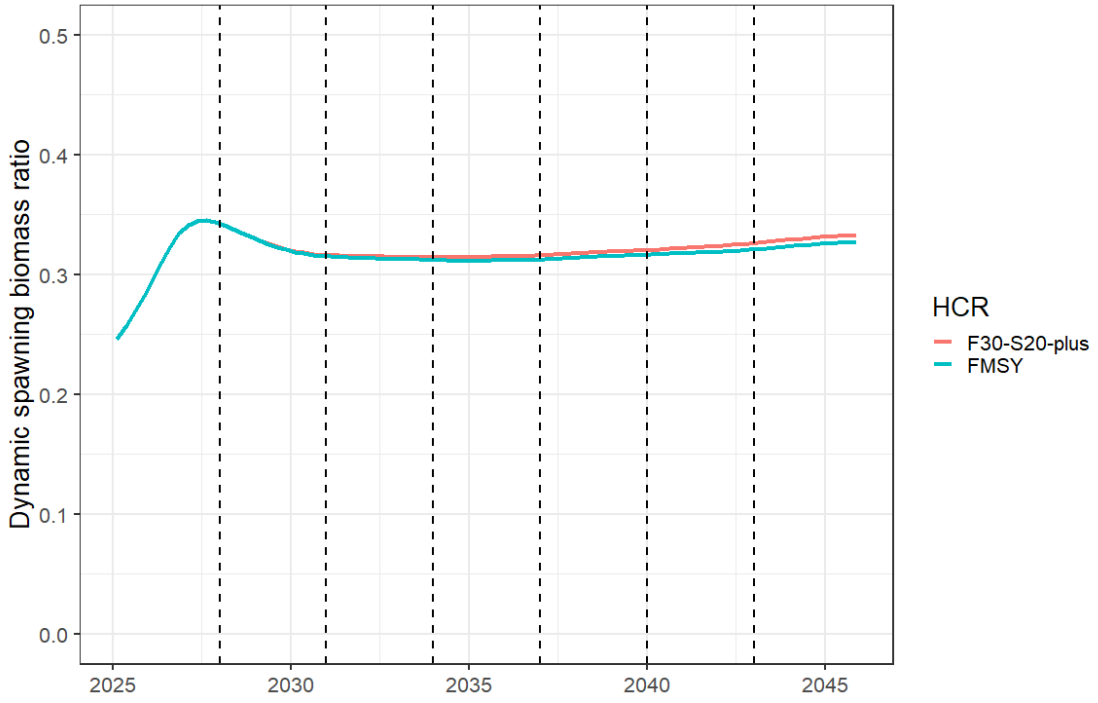
Component	HCR2_20cap	HCR2_nocap	HCR3_20cap	HCR3_nocap
F_{max}	$F_{30\%}$	$F_{30\%}$	$F_{40\%}$	$F_{40\%}$
$S_{control}$	$S_{30\%}$	$S_{30\%}$	$S_{30\%}$	$S_{30\%}$
Max change in closure	10 days ($S > S_{control}$) **20 days ($S < S_{control}$)**	10 days ($S > S_{control}$) **No cap ($S < S_{control}$)**	10 days ($S > S_{control}$) **20 days ($S < S_{control}$)**	10 days ($S > S_{control}$) **No cap ($S < S_{control}$)**

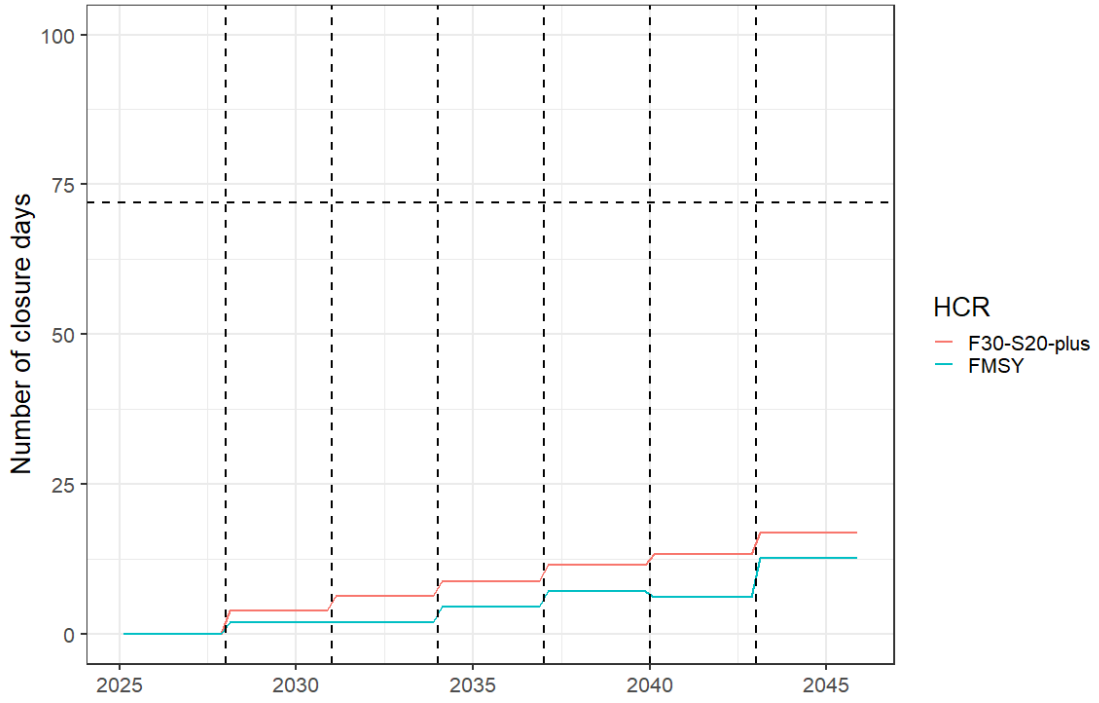


Evaluate the performance of some HCRs

- Removing the 10-day cap when S<Scontrol intends to impose fast response to stock depletion but does not work well:
  - Instability (HCR2): large increases in the closure are occasionally observed due likely to recruitment-induced stock depletion
  - Inflexibility (HCR3): management action can get "stuck" in the overly conservative zone when S rebuilds above Scontrol due to the 10-day cap when S>Scontrol
- A 20-day cap when S<Scontrol allows faster responses to depletion while preserving stability:
  - HCR2: get rid of those extremely large increases in the closure
  - HCR3: the stock reaches the target level after just two cycles

Evaluate the performance of additional HCRs





HCR	Prob dSBR > 0.2	Prob SBR > 0.077	Prob $S > 0.5S_{MSY}$	Prob Kobe = green	AAV in catch	P (change = 20)	Annual PS catch	Annual LL catch	Fishery closure	CPUE ratio
F30-S20-plus	91.4	99.5	99.6	80.9	7.6	3.6	53392	51533	9	2.05
FMSY	90.7	99.5	99.4	79.4	7.9		53651	51565	5	2.03