



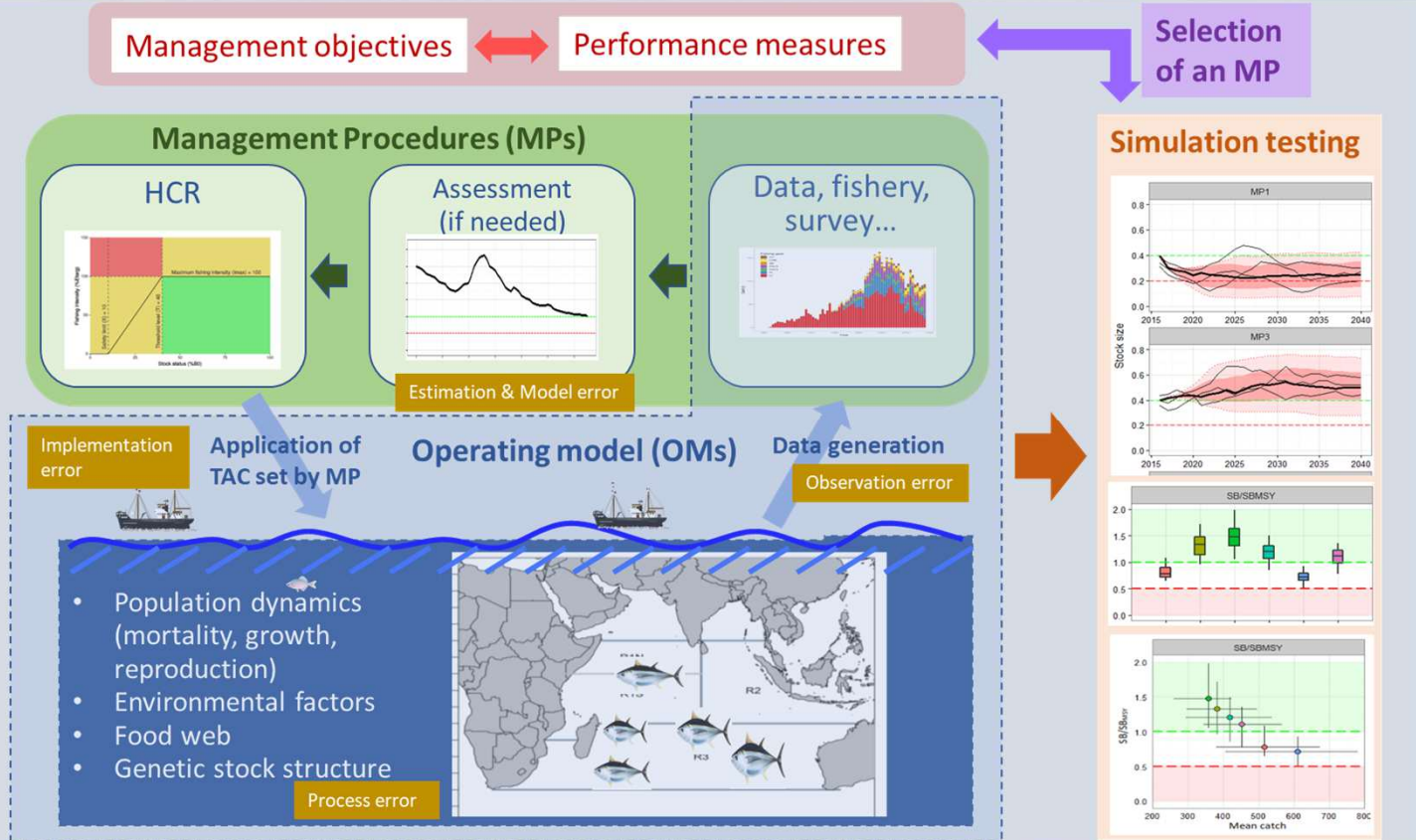
MANAGEMENT STRATEGY EVALUATION (MSE) INTRODUCTION

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May 9, 2026@Male, Maldives

MSE Process

1. Identification of **Management objectives** and **performance measures**
2. Development of **Management Procedures (MPs)**
3. Development of **Operating Models (OMs)**
4. **Simulation testing** of MPs with the OMs
5. **Selection of an MP** based on simulation performance
6. **Implementation of the MP**



What is **Management Strategy Evaluation (MSE)** ?

“a simulation framework incorporating uncertainty to evaluate the performance of candidate Management Procedures (MPs) against pre-determined management objectives”

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Management Procedures (MPs)

- a pre-defined operational rule used to set a Catch Limit (or level of fishing effort)
 - ✓ Data acquisition (catch series, CPUE series etc.)
 - ✓ Understanding the stock condition (via an internal assessment or index trend etc.)
 - ✓ Harvest Control Rule for implementation
- “Model-based” (with a stock assessment model) and “Empirical-based” (data-driven)
- Designed to be robust under uncertainty

What is **Management Strategy Evaluation (MSE)** ?

“a simulation framework incorporating uncertainty to evaluate the performance of candidate Management Procedures (MPs) against pre-determined management objectives”

Simulation framework incorporating uncertainty

- Create a virtual population and virtual fisheries in computer for future operation (operating models, with several elements of uncertainty)
- Catch is determined according to an MP
- Population reacts to impact of catch (e.g. population decreases if catch limit is too high)
- Continue until management period ends, repeats many times to account for stochastic uncertainty

What is **Management Strategy Evaluation (MSE)** ?

“a simulation framework incorporating uncertainty to evaluate the performance of candidate Management Procedures (MPs) against pre-determined management objectives”

Management objectives and performance indicators

Objectives

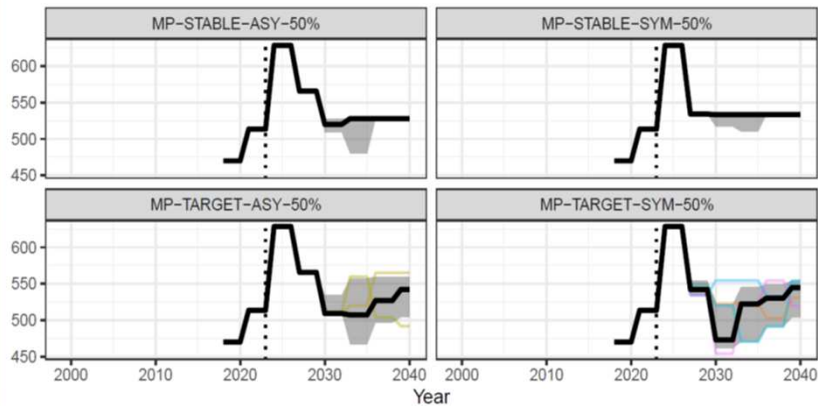
- ✓ *Biological safety : Sustainability of populations, recovery to target levels*
- ✓ *Catch : High yields, stability across years*
- ✓ *Risk-averse : Precautionary approach, minimizing probability of stock depletion*

Performance indicators

- *To quantify the expectations and probabilities of the achievements and risks*

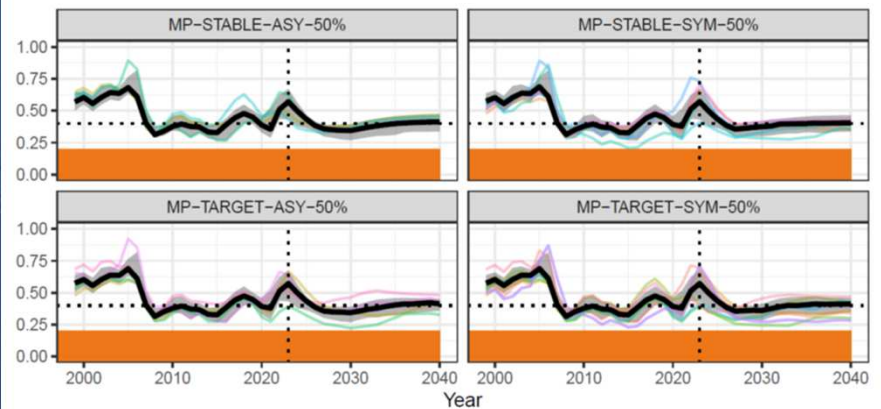
- **Comprehensiveness, Transparency and Dialogue**
- Consider in advance **uncertainty** in data, model, estimation, projection, implementation etc.
- Ensure a certain level of **robustness** of management performance to uncertainty
- Information is available in advance for some **likely trajectories** and their ranges for biomass, catch, etc. after implementing an MP

Absolute TAC



(a) MP's tuned to 50% probability of being in the target quadrant.

Relative SSB



(a) MP's tuned to 50% probability of being in the target quadrant.

TIMELINE OF MP DEVELOPMENT AND ADOPTION (2016–2025)

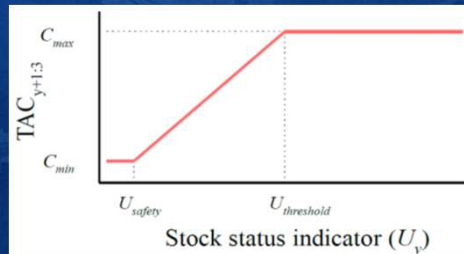
- 2016: Resolution 16/09 establishment of the Technical Committee on Management Procedures (TCMP)
- 2016-2018: Initiation of species-specific MSE work for **YFT, SKJ, ALB, SWO, and BET**
- 2016: Resolution 16/02 adoption of **SKJ Harvest Control Rule (HCR)** (not full MP)
- 2021: Resolution 21/03 adoption of **SKJ HCR** – superseded 16/02 SKJ HCR
- 2022: Resolution 22/03 MP for **BET** developed through MSE process
- 2024: Resolution 24/07 MP for **SKJ** superseded 21/03 SKJ HCR (Full MP now - developed through MSE process)
- 2025: Resolution 25/07 MP for **SWO** → first RFMO to have a working MP for SWO - developed through MSE process
- 2025: Resolution 25/10 TCMP supersedes 16/09 establishment of the **TCMP**

	Bigeye	Skipjack	Swordfish
Stock status	2025	2023	2023
CMM/Prop	22/03 (MP), 23/04 (Catch limits)	24/07 (MP)	24/08 (MP)
Tuning criterion	Prob(Kobe G) = 60%	Prob(B > B40% & E < E40%) = 50%	Prob(Kobe Green) = 60%
MP type	Model-based (harvest)	Data-based (stable)	Data-based (fast)
Inputs for MP	Time series of catch & std-CPUE	Time series of std-CPUE	Recent CPUE
Constraints	15% maximum change	Asymmetric 15%(up)-10% (down)	Asymmetric 15% (up) - 10% (down)

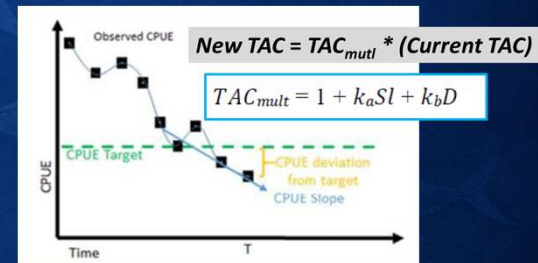
Fishing intensity is controlled based on a **simple assessment**



TAC is directly controlled based on **stock status indicator (CPUE)**



TAC is updated by **CPUE trend** and its **difference against target**

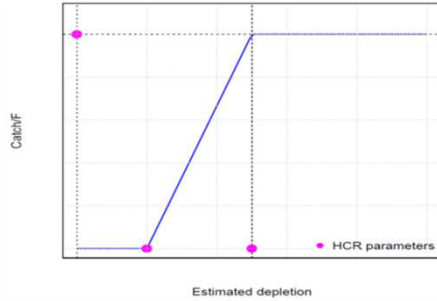


BIGEYE MP



MP1 Harvest

Model-based with simple stock assessment

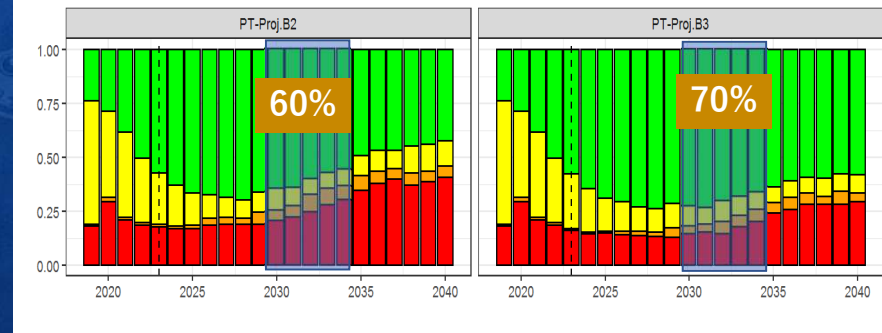
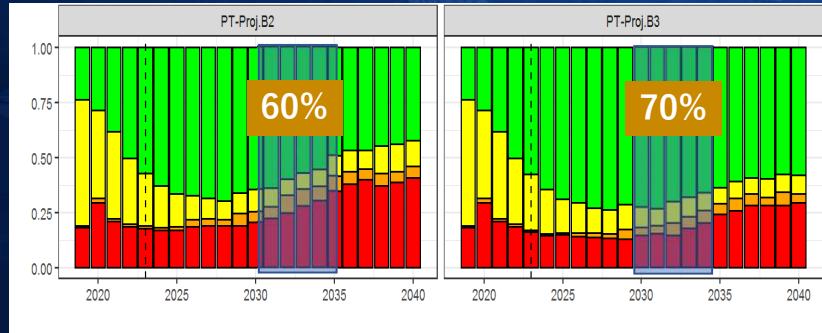
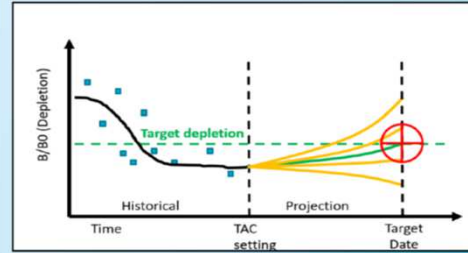


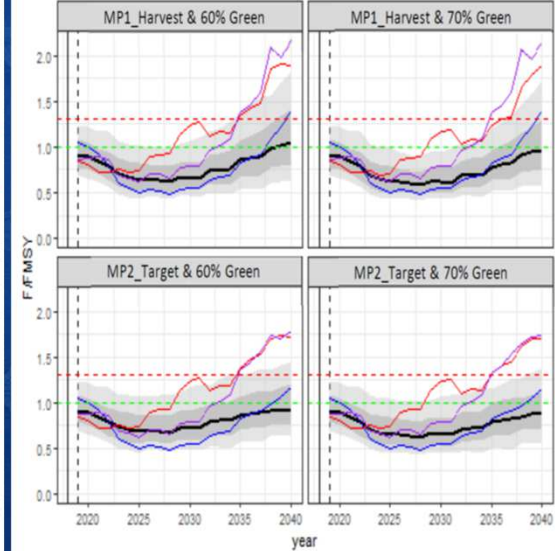
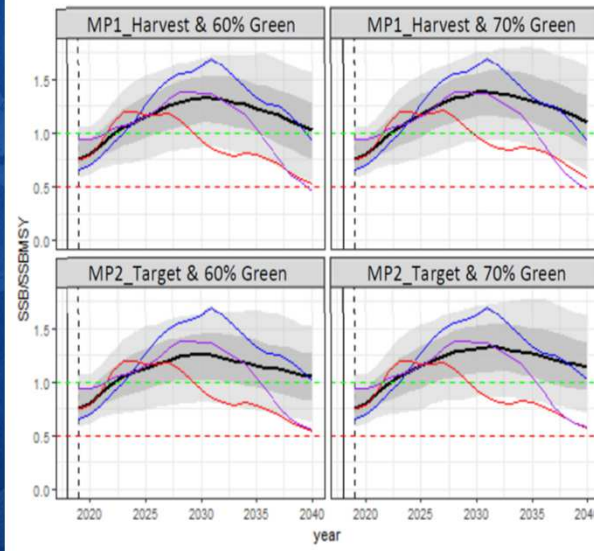
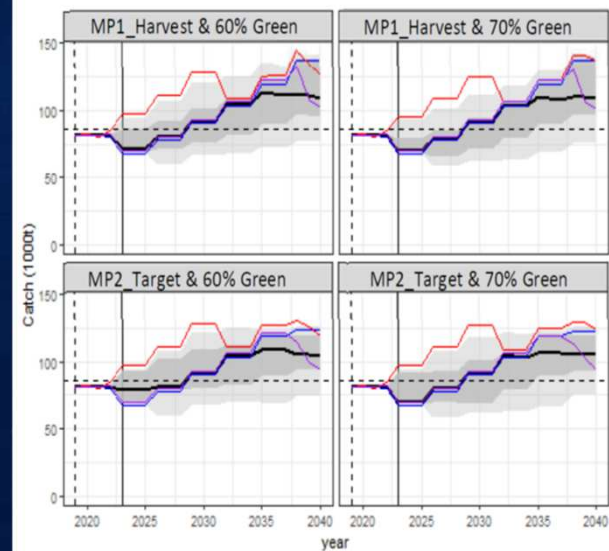
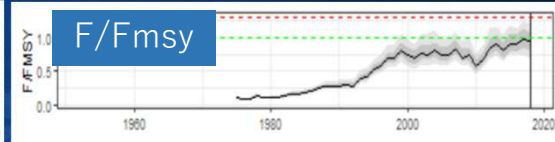
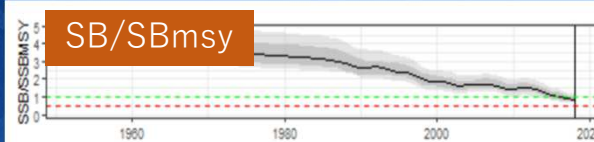
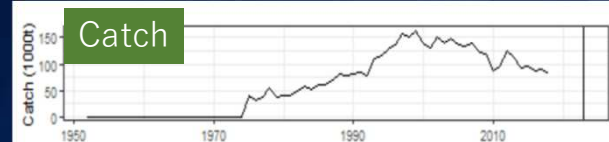
Model-based MP with internal projection

MP2 Target

PTRE-based MP with internal projection

- 1) Fit PETR Model
- 2) Find constant TAC that hits target depletion at target date





- MP1: higher ave catch, higher variation
- MP2_60%: Initial catch reduction seems low

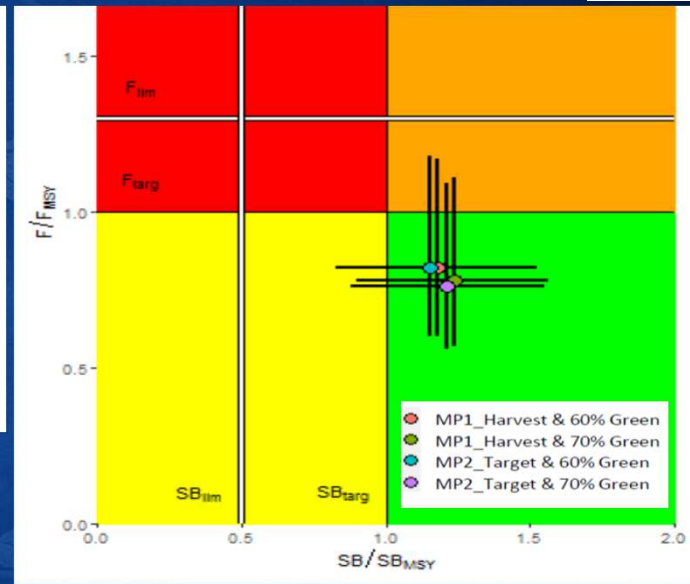
Stochastic variation at the end in MP1 tends to be slightly larger than that in MP2

Stochastic variation in MP1 tends to be slightly larger than that in MP2

BIGEYE TUNA (SUMMARY PLOTS)



- MP1_Harvest & 60% Green
- MP1_Harvest & 70% Green
- MP2_Target & 60% Green
- MP2_Target & 70% Green



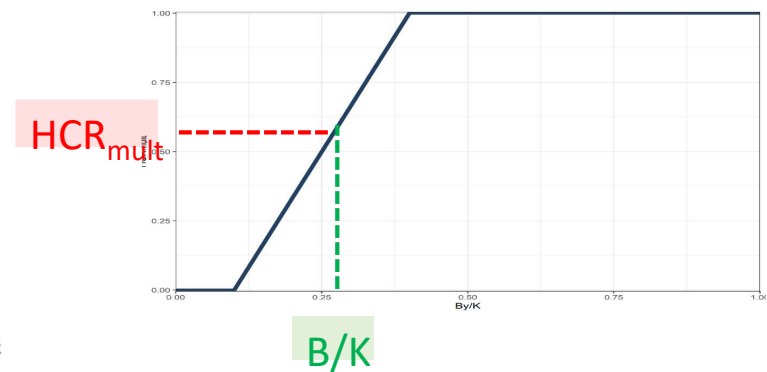
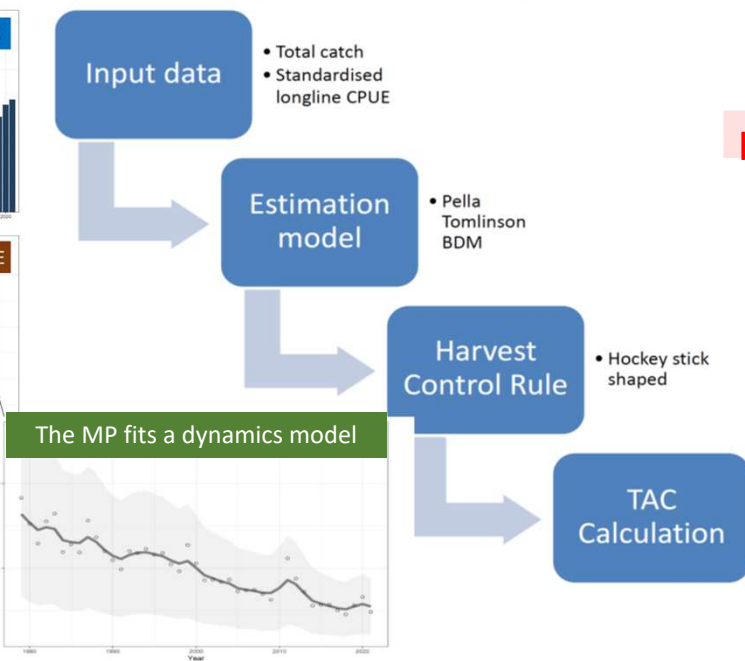
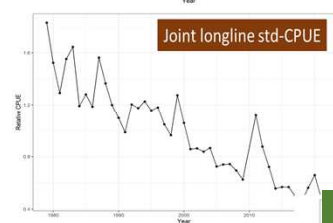
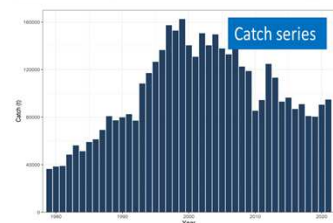
BIGEYE TUNA (SUMMARY TABLE)

	Performance Measure				
MP	SB/SB _{MSY}	Prob(Green)	Prob(SB>limit)	Mean Catch (t)	Catch Variability (%)
MP1_Harvest 60% Green	1.18 (1.00-1.36)	0.63	0.97	99.3 (85.6-106.1)	5.06
MP2_Target 60% Green	1.15 (0.96-1.32)	0.63	0.97	97.7 (86.0-103.6)	4.23
MP1_Harvest 70% Green	1.24 (1.07-1.40)	0.69	0.98	96.6 (83.7-104.6)	5.08
MP2_Target 70% Green	1.21 (1.04-1.39)	0.69	0.98	95.8 (82.8-101.6)	4.28

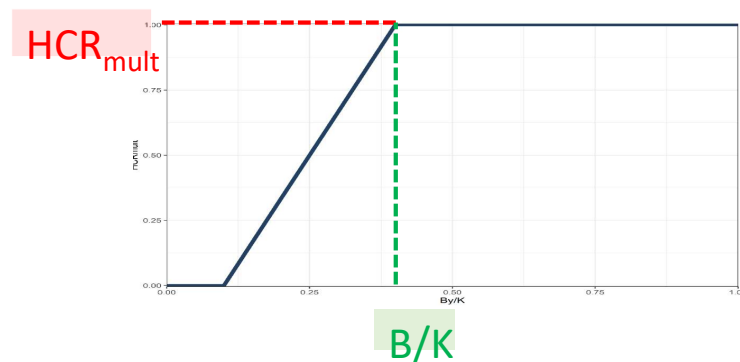
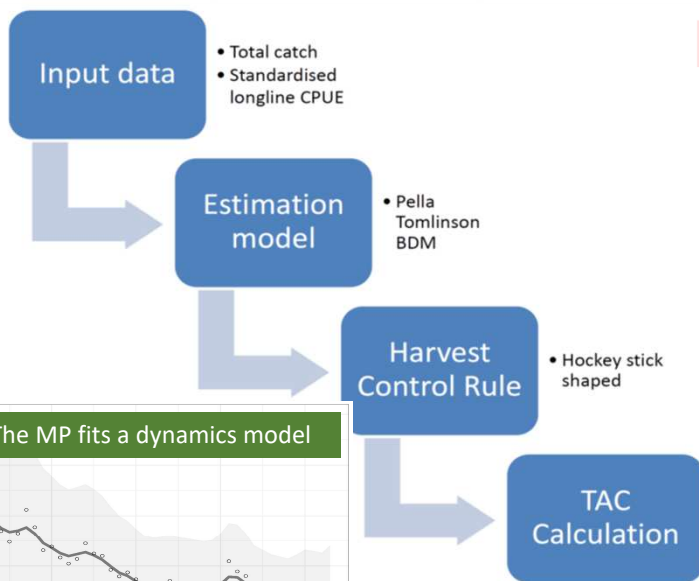
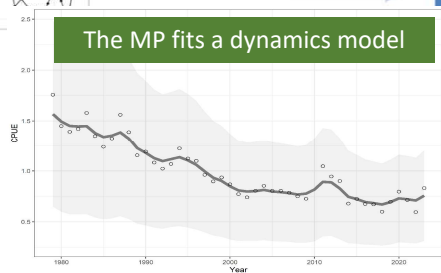
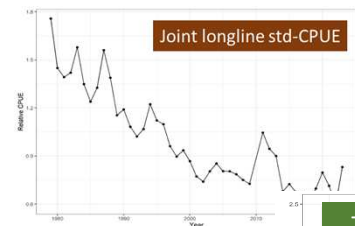
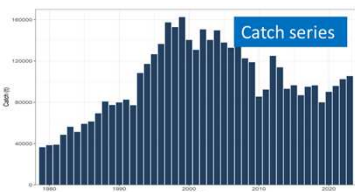
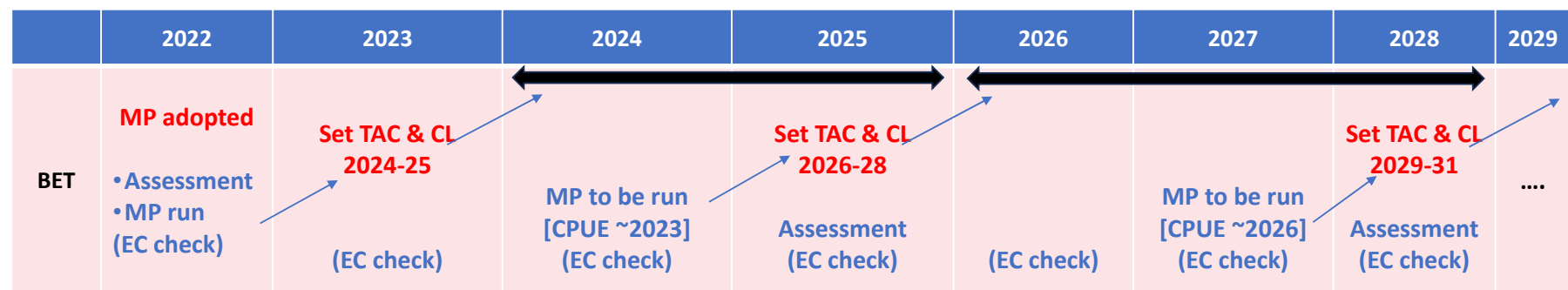
(80% interval)

Management procedure

2. The adopted management procedure for bigeye tuna known as MP1 Harvest is described in Annex I (MP).
3. Consistent with the adopted management objectives of the Commission, the management procedure is designed to achieve:
 - a) a 60% probability that the bigeye tuna spawning stock biomass achieves the target reference point of SB_{MSY}^1 by 2034-2038;
 - b) the bigeye tuna spawning stock biomass avoids breaching the interim limit reference point specified in Resolution 15/10 with a high probability;and operates with the following constraint:
 - c) the maximum increase or decrease in the TAC shall be 15% relative to the previous TAC.



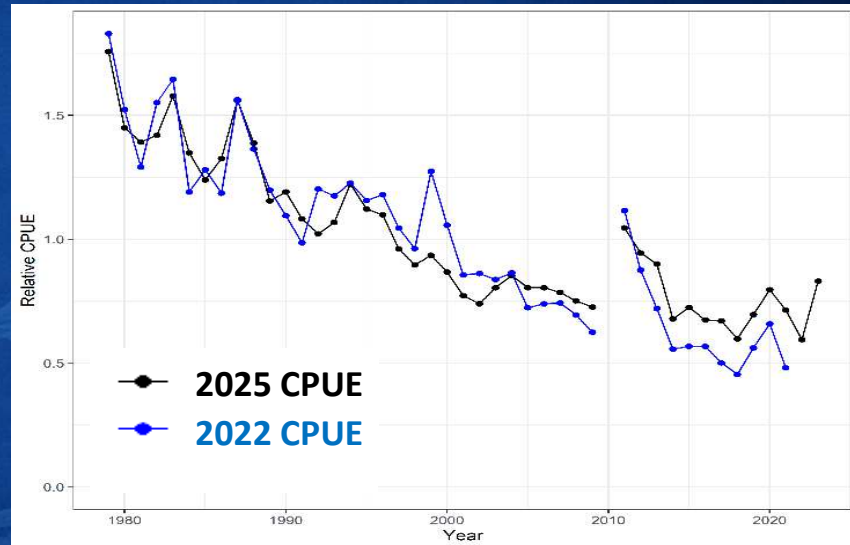
$TAC_{new} = 68,404$ t
 (>15% lower than 2021 catch of 94,803 t)
Recommended TAC (endorsed by SC)
= 80,583 t (15% below 2021 catch)



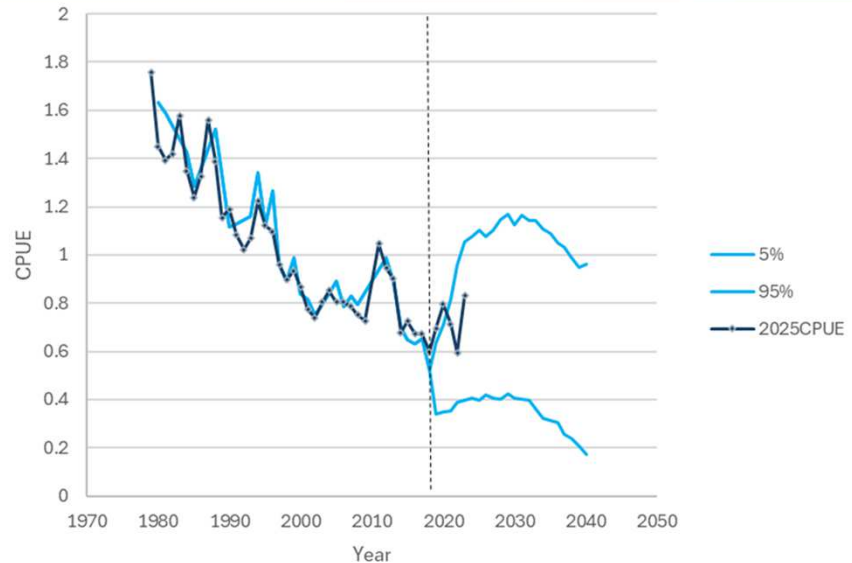
$TAC_{new} = 175,005 \text{ t}$
 (>15% high than 2024-25 TAC of 80,583 t)

Recommended TAC (endorsed by SC) = 92,670 t (15% above current TAC)

- CPUE was the only exceptional circumstance identified
- The CPUE standardization differs from the specified methods:
 - Data: aggregated in 2022; operational in 2025 as specified in 22/03
 - Model: delta log-normal in 2022; lognormal models in 2025
 - sampling and exclusion of some data in 2021-2023 in 2025 CPUE
 - Generally similar trend than 2022 and 2019 in all regions
- No other exceptional circumstances were detected in the 2024 review



- The historical period 1979-2018 shows similar trends.
- The 2025 CPUE is within the MSE range 2021-2023.
- The 2025 CPUE series is slightly above the 95% confidence bound of the MSE projected range in 2019 and 2020 -> **a positive exceptional circumstance**
- The impact may include slightly higher TAC results from the MP, which is, however, constrained by the 15% TAC change constraint component of the MP.
- Thus, no further actions are required to proceed with the recommended TAC from the BET MP.



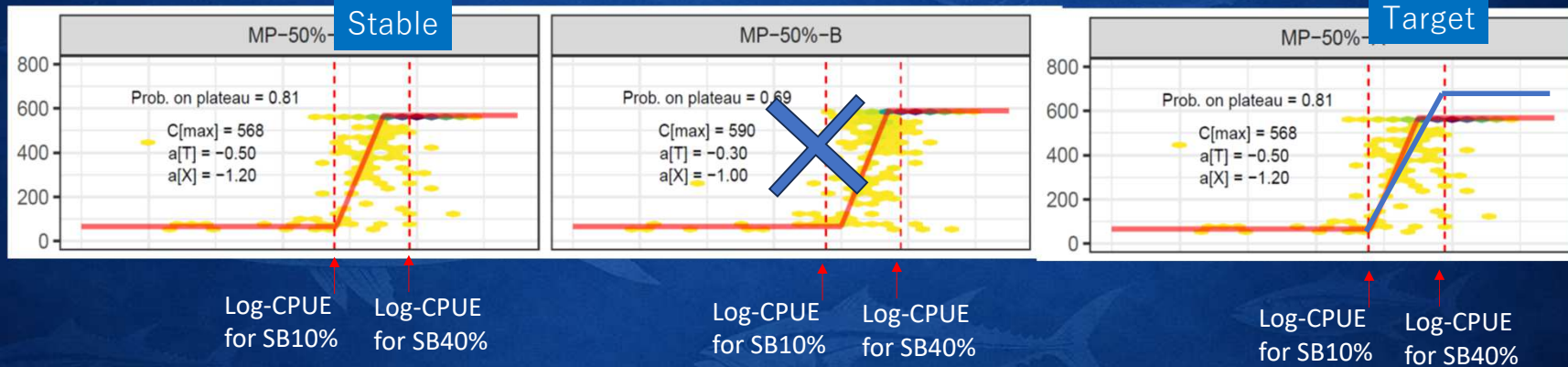
From Preece and Williams (2025)
IOTC-2025-TCMP09-INF05



SKIPJACK MP

12 candidate MPs

- **3 tuning criteria** (50,60,70%)
- 3 MP types (originally) => **2 MP types** (“Stable” and “Target”)

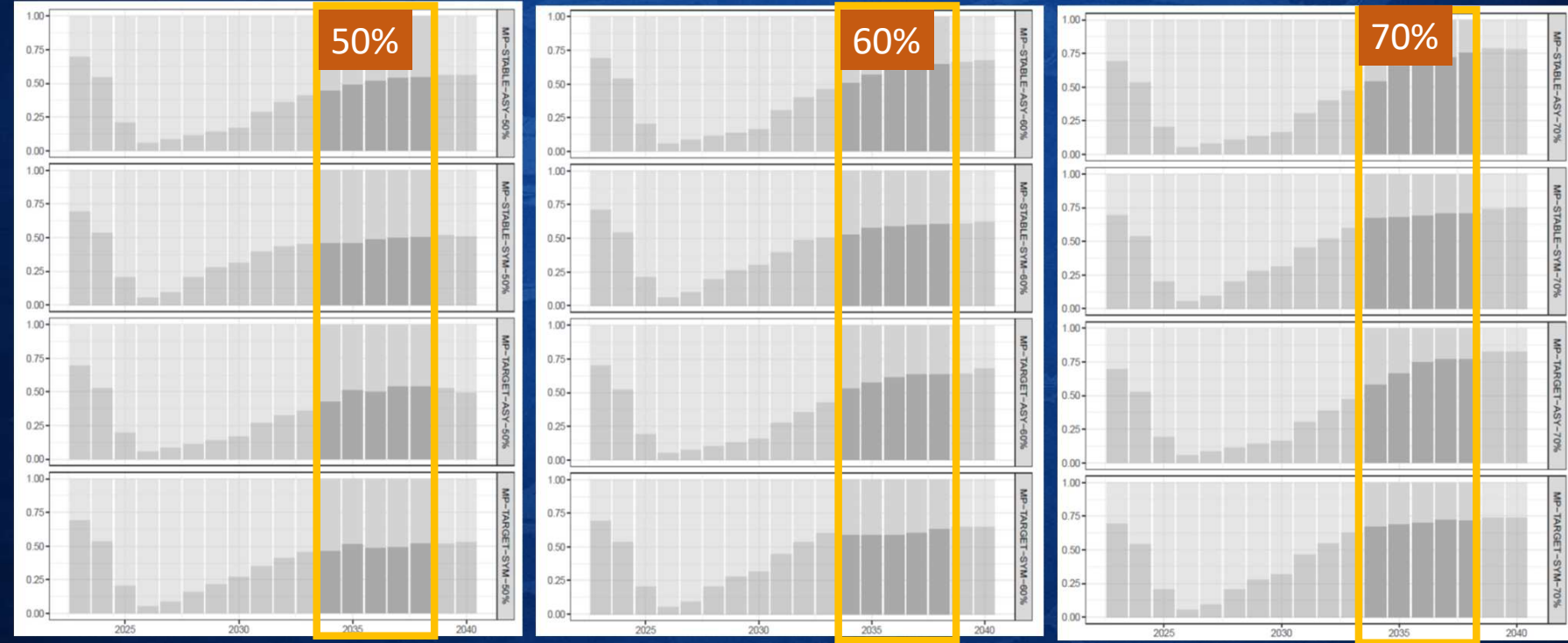


• 2 TACConstraint options

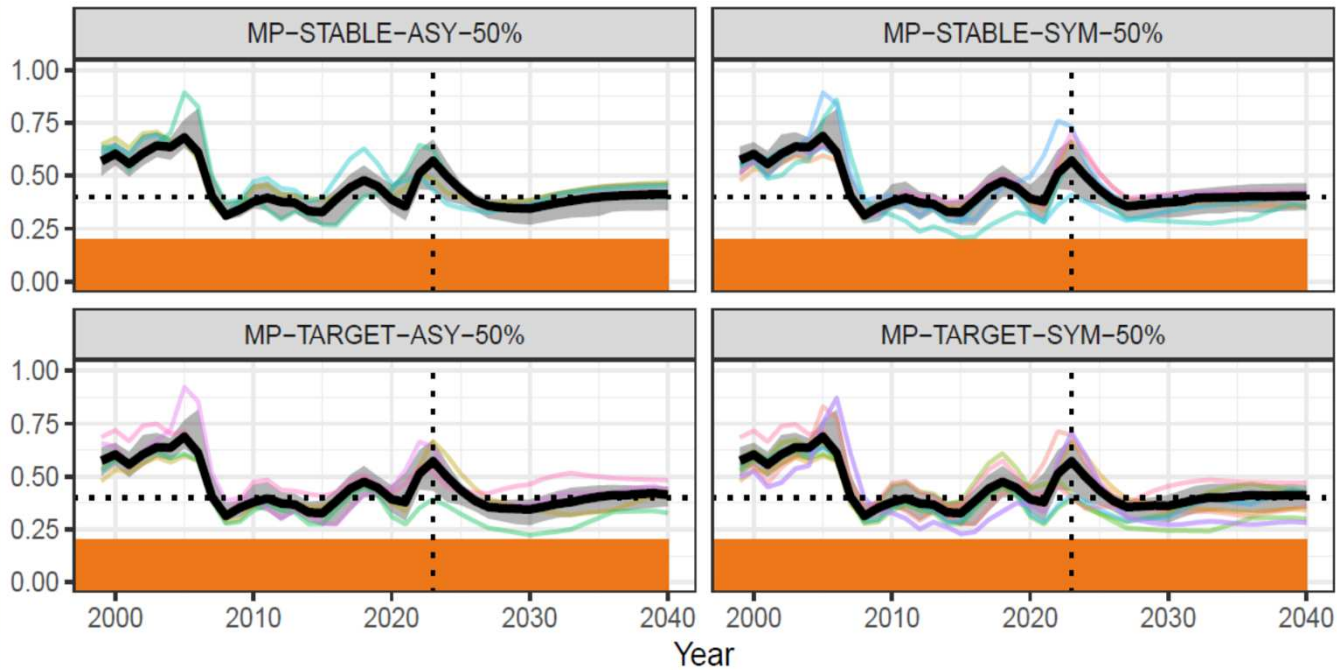
- Symmetric 15% (upward and downward)
- Asymmetric 15% (upward) and 10% (downward)

12 candidate MPs

- 3 tuning criteria $\text{Prob}(B > B_{40\%} \ \& \ E < E_{40\%}) = 50, 60, 70\%$

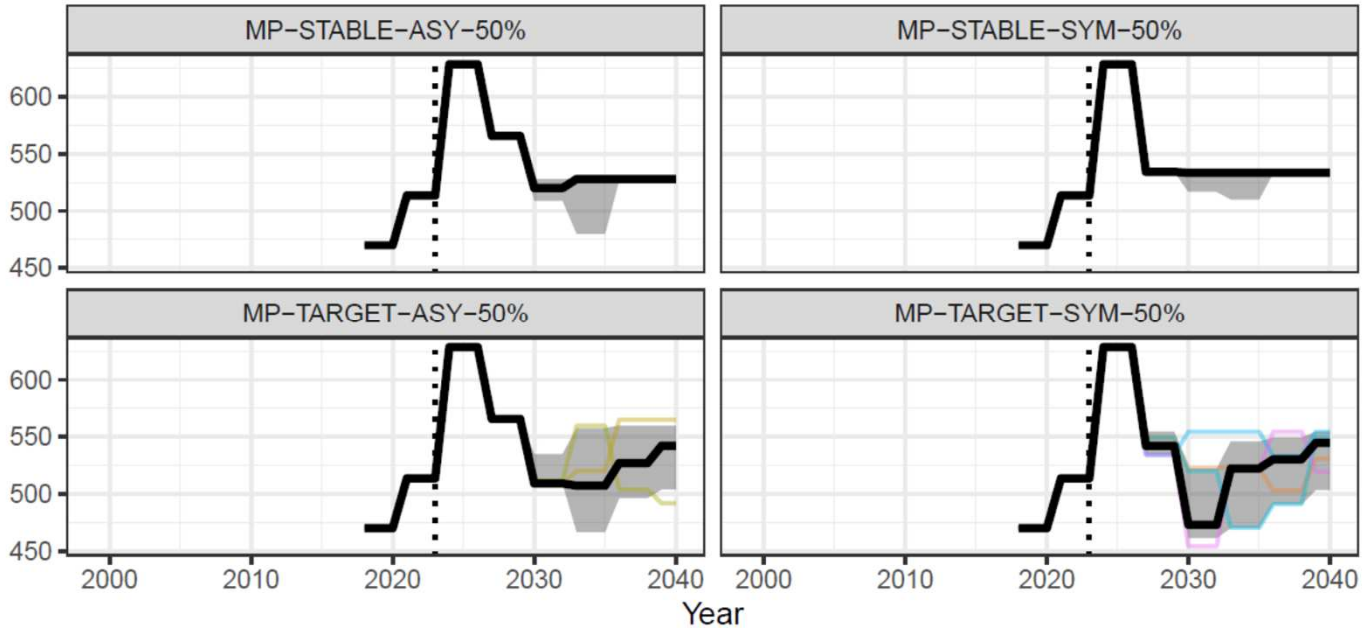


Relative SSB



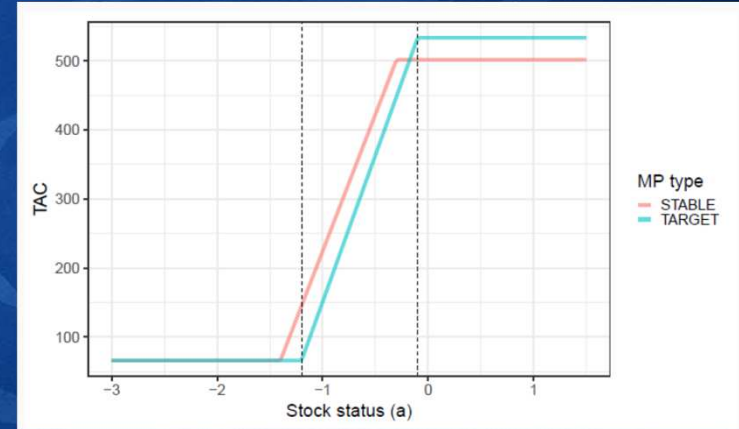
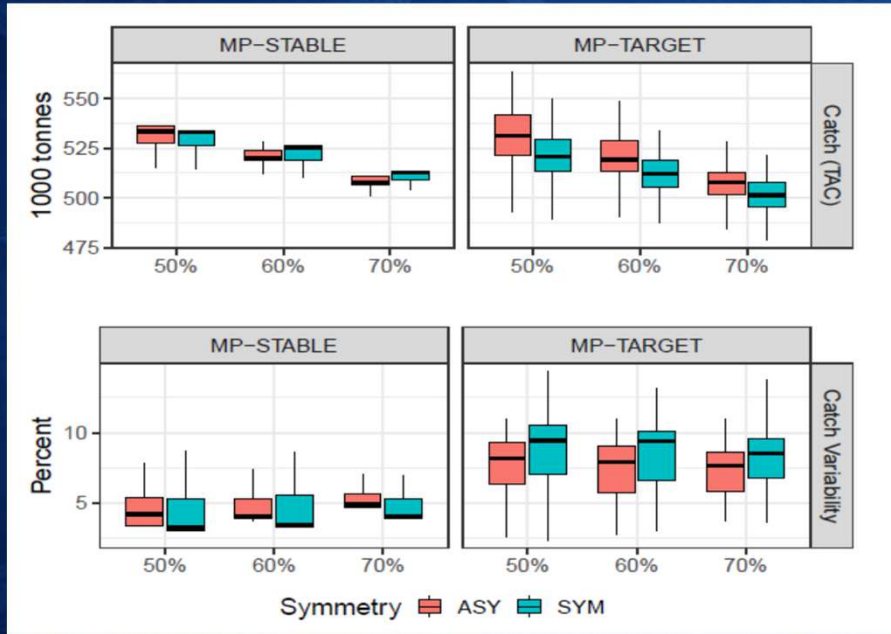
(a) MP's tuned to 50% probability of being in the target quadrant.

Absolute TAC



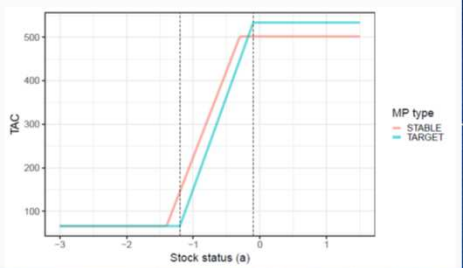
(a) MP's tuned to 50% probability of being in the target quadrant.

SKIPJACK TUNA (BOX PLOT)



- The 'Stable' MP-type provides higher average TAC and lower variability. The 'Target' MP-type is more responsive but more variable.
- Asymmetric TAC change limit increases frequency of TAC changes but improves stability.

SKIPJACK TUNA (SUMMARY TABLE)



MP	Total Catch	Lower TAC Quantile	Number of TAC changes	Average TAC change	Pr. SSB above target	Pr. SSB above MSY
MP-STABLE-ASY-50%	530.46	517.14	3	4.18	0.38	0.92
MP-STABLE-ASY-60%	521.3	512.86	3	4.08	0.43	0.92
MP-STABLE-ASY-70%	512.05	507.41	3	4.91	0.48	0.93
MP-STABLE-SYM-50%	529.63	518.24	3	3.24	0.41	0.94
MP-STABLE-SYM-60%	523.29	513.93	2	3.43	0.46	0.94
MP-STABLE-SYM-70%	513.78	506.28	2	4.02	0.54	0.96
MP-TARGET-ASY-50%	529.12	515.03	5	8.16	0.38	0.93
MP-TARGET-ASY-60%	520.27	509.66	5	7.92	0.43	0.94
MP-TARGET-ASY-70%	511.81	504.91	5	7.67	0.49	0.94
MP-TARGET-SYM-50%	519.22	505.62	5	9.41	0.41	0.95
MP-TARGET-SYM-60%	511.55	499.73	5	9.38	0.51	0.96
MP-TARGET-SYM-70%	503.87	492.17	4	8.53	0.54	0.96

- **Tuning criteria: The 70% tuning was excluded as overly conservative.** The EU proposed 50%, while some members supported 60% as a good trade-off.
- **MP type:** The ‘Stable’ MP-type provides higher average TAC and lower variability; the ‘Target’ MP-type is more responsive but more variable. **The TCMP tentatively agreed on the ‘Stable’ MP-type.**
- **TAC change limit:** Asymmetric TAC change limit increases frequency of TAC changes but improves stability. **The TCMP tentatively agreed on the asymmetric clause.**
- **Climate change:** Not explicitly included in the MP. Recent high recruitment may be climate-driven but projections use long-term conservative recruitment.
- **Recruitment anomaly:** Above-average recent recruitment led to a high TAC (628,262 tonnes), but this is considered an anomaly. MPs tested will reduce TAC in the initial application period.
- **Plateau effect:** Even if recruitment and CPUE remain high, TAC may not increase due to the plateau in the MP.

- **Final recommendation:** TCMP recommended adoption of the EU proposal with:
 - **50% probability of being at the skipjack target reference point (40% B₀) in 2034–2038**
 - **Stable MP-type parameterisation**
 - **Asymmetric TAC change clause**
- **Ecosystem effects:** Skipjack catches affect yellowfin and bigeye (overfished). TCMP recommended SC incorporate ecosystem effects in the next revision.
- **Compliance:** Past catches exceeded limits; TCMP recommended Commission ensure TAC compliance when MP is applied.
- **Future monitoring:** TCMP requested EU to include provision for SC to monitor future recruitments under skipjack exceptional circumstances.

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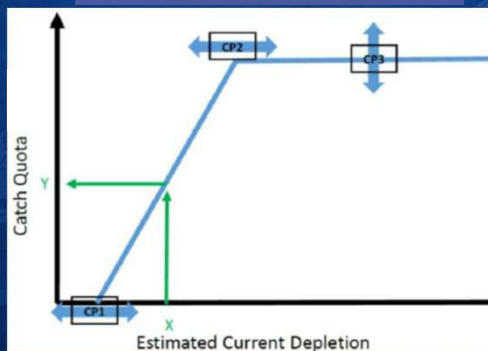
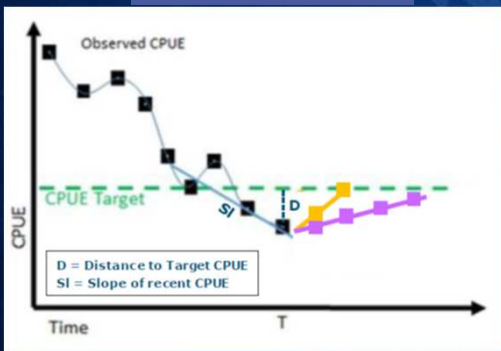
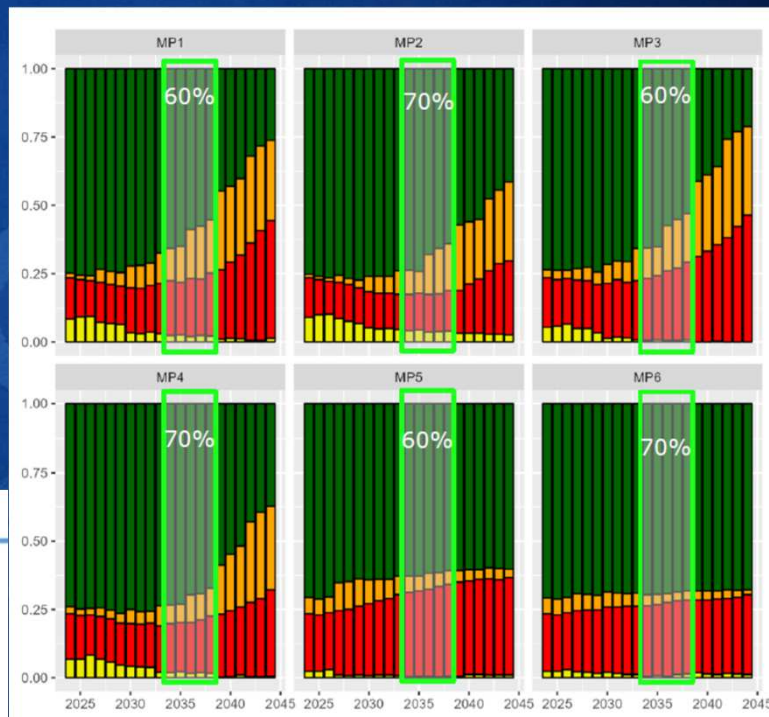
SWORDFISH MP

6 candidate MPs

MP name	descriptor	MPType	Tuning objective $P(\text{Green})=$	TAC stabilizer (max up- max down)
MP1	CPUE_Fast_60%_15-10	Faster reacting data-based	60%	15-10
MP2	CPUE_Fast_70%_15-10	Faster reacting data-based	70%	15-10
MP3	CPUE_Slow_60%_15-10	Slower reacting data-based	60%	15-10
MP4	CPUE_Slow_70%_15-10	Slower reacting data-based	70%	15-10
MP5	Modelbased_60%_15-10	Model based	60%	15-10
MP6	Modelbased_70%_15-10	Model based	70%	15-10

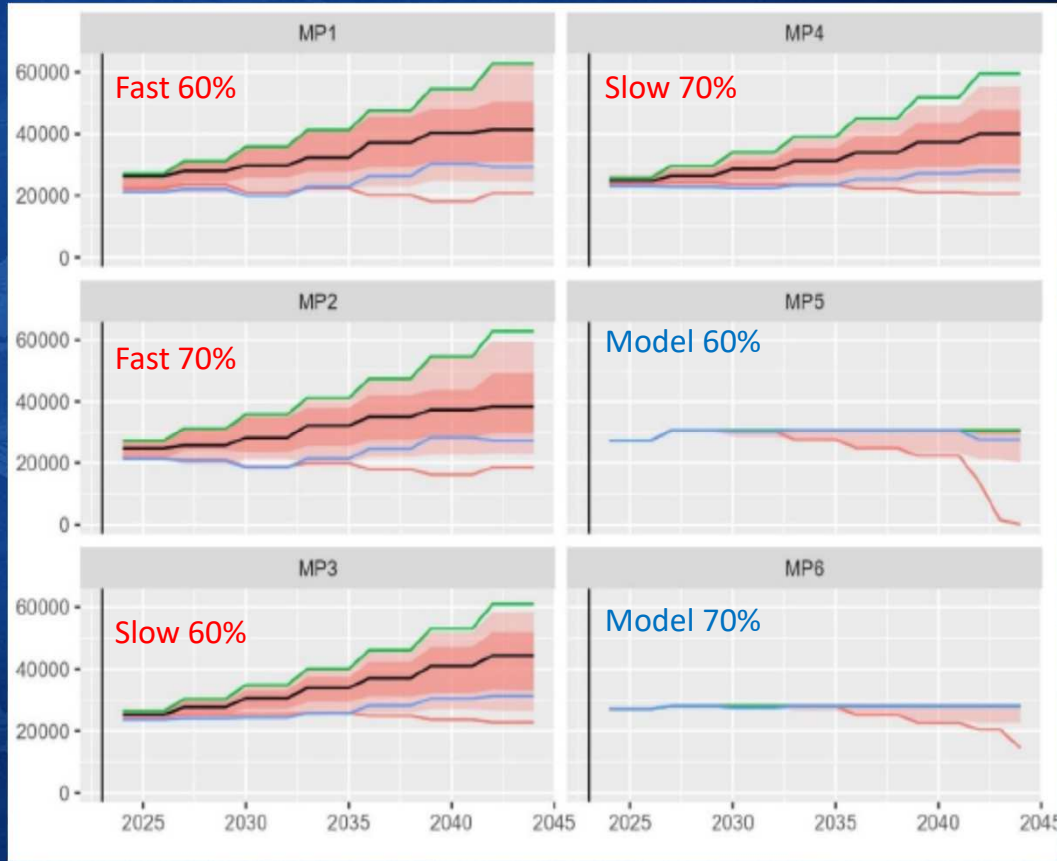
MP 1-4 (CPUE)

MP5-6 (model based)



6 candidate MPs

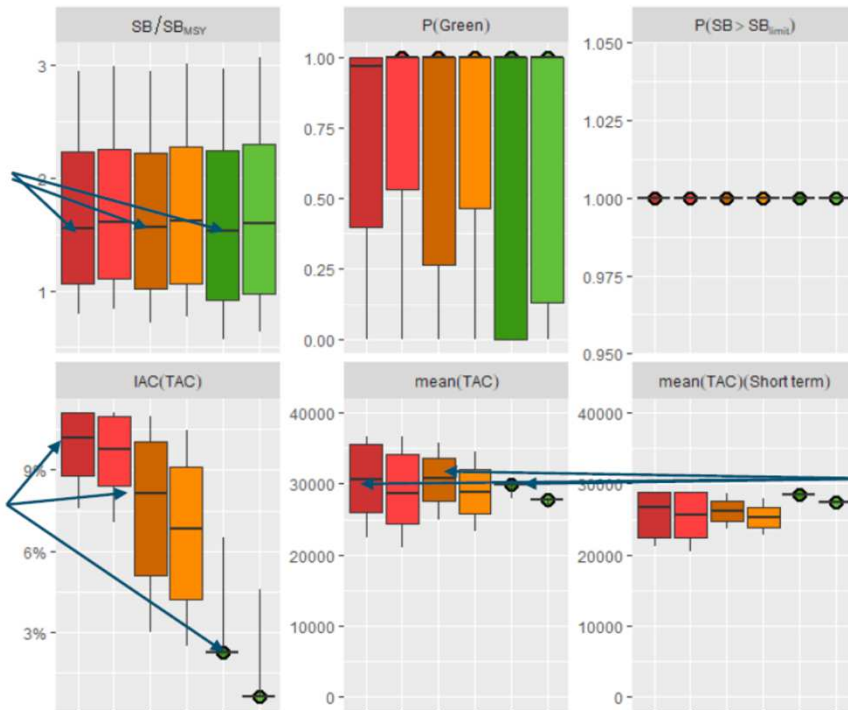
MP name	descriptor	MPtype	Tuning objective $P(\text{Green}) =$	TAC stabilizer (max up- max down)
MP1	CPUE_Fast_60%_15-10	Faster reacting data-based	60%	15-10
MP2	CPUE_Fast_70%_15-10	Faster reacting data-based	70%	15-10
MP3	CPUE_Slow_60%_15-10	Slower reacting data-based	60%	15-10
MP4	CPUE_Slow_70%_15-10	Slower reacting data-based	70%	15-10
MP5	Modelbased_60%_15-10	Model based	60%	15-10
MP6	Modelbased_70%_15-10	Model based	70%	15-10



MP performance (2024-2038)

More impact of tuning objective than MP type
 Large uncertainty in future stock size but slightly larger for model-based MPs)

Stable catches for model-based MP, more variable for data-based MP



MP1	} CPUE rule FAST (data based)
MP2	
MP3	} CPUE rule SLOW (data based)
MP4	
MP5	} Hockey stick HCR (model based)
MP6	

High probability of $SB > SB_{lim}$

High probability of being in Kobe green

Higher TAC for data-based MP with wider distribution, but opposite for the short-term

SWORDFISH MSE (SUMMARY TABLE)

MP	SB/SBMSY	p(SB>=SBMSY)	p(SB>SBlim)	p(Green)	mean(TAC)	C/MSY	IAC(TAC)
MP1	1.55 (0.79-2.95)	1 (0.00-1.00)	1 (1.00-1.00)	0.61 (0.00-1.00)	30561 (22351-36599)	0.95 (0.71-1.15)	10.16 (7.55-11.11)
MP2	1.62 (0.84-2.99)	1 (0.00-1.00)	1 (1.00-1.00)	0.69 (0.00-1.00)	28643 (21062-36599)	0.9 (0.69-1.10)	9.75 (7.07-11.11)
MP3	1.57 (0.71-2.95)	1 (0.00-1.00)	1 (1.00-1.00)	0.59 (0.00-1.00)	30802 (24993-35728)	0.97 (0.70-1.15)	8.13 (3.03-10.96)
MP4	1.62 (0.77-3.01)	1 (0.00-1.00)	1 (1.00-1.00)	0.7 (0.00-1.00)	28809 (23277-34506)	0.92 (0.66-1.08)	6.84 (2.52-10.48)
MP5	1.54 (0.57-2.97)	1 (0.00-1.00)	1 (1.00-1.00)	0.62 (0.00-1.00)	29828 (28012-29828)	0.93 (0.60-1.20)	2.25 (2.25-6.52)
MP6	1.6 (0.63-3.07)	1 (0.00-1.00)	1 (1.00-1.00)	0.69 (0.00-1.00)	27828 (26580-27828)	0.87 (0.56-1.12)	0.62 (0.62-4.57)

Median values (10% and 90% quantiles)

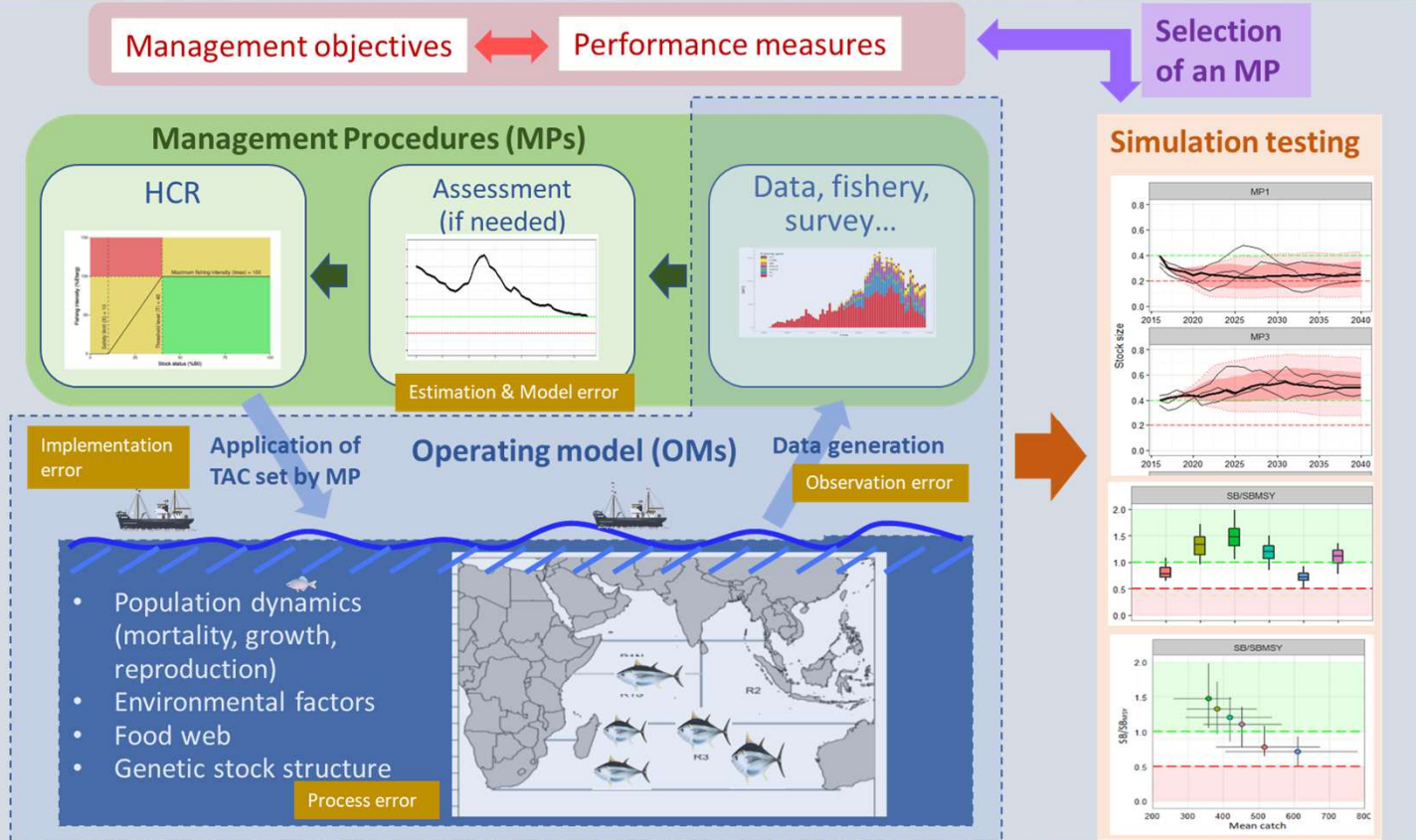
Performance over the period 2024-2038

The background is a solid blue gradient with a pattern of fish swimming in various directions. The fish are rendered in a lighter shade of blue, creating a subtle, repeating pattern. The text "BEFORE ENDING..." is centered in the middle of the image in a white, bold, sans-serif font.

BEFORE ENDING...

MSE Process

1. Identification of **Management objectives** and **performance measures**
2. Development of **Management Procedures (MPs)**
3. Development of **Operating Models (OMs)**
4. **Simulation testing** of MPs with the OMs
5. **Selection of an MP** based on simulation performance
6. **Implementation of the MP**



MSE PROCESS

1 Identification of **Management objectives** and **Performance measures**

2 Development of **Operating Models (OMs)**

3 Development of **Management Procedures (MPs)**

4 **Simulation Testing** of MPs with the OMs.

5 **Selection of an MP** based on simulation performance

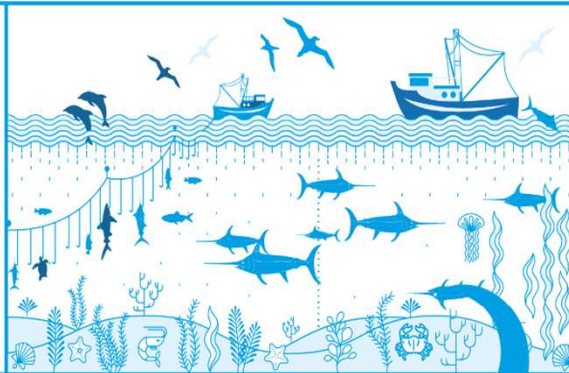
6 **Implementation of the MP**

1 MANAGEMENT OBJECTIVES

PERFORMANCE MEASURES

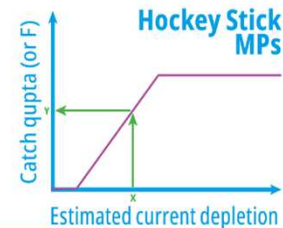
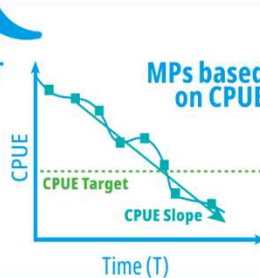
2 OPERATING MODELS (OMS)

Population dynamics
(mortality, growth, reproduction)



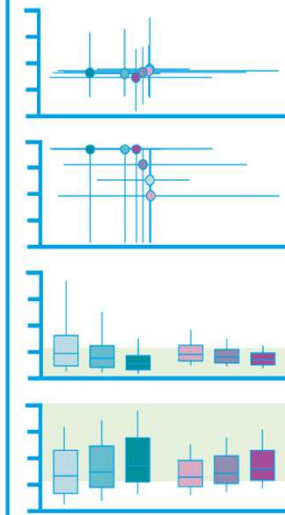
3 MANAGEMENT PROCEDURES (MPs)

Application of TAC set by MP



5 MP SELECTION

4 SIMULATION TESTING





INTRODUCTION
Fisheries are a complex dynamic system. We don't know exactly how it functions and interacts with the environment and society.

Our ability to predict how stocks will respond to exploitation is limited and control mechanisms we have are imperfect. Finding management solutions through trial and error is difficult for various reasons, not to mention the ethical ones (conducting experiments on fisheries would entail deliberately depleting them and risking stock collapses). Thus, simulations are an attractive option. This is the essence of the Management Strategy Evaluation (MSE) approach — it's a way to identify those exploitation strategies that are likely to achieve management objectives while avoiding unacceptable risks.

Management Strategy Evaluation
Management strategy evaluation represents a paradigm shift — no longer beholden to the accuracy of stock assessments, it is a step towards proactive and robust decision-making. In practice, MSE is a type of quantitative risk assessment that starts with a relatively narrow scope — ecosystem, or explicitly social, cultural, or economic aspects need to be considered separately, as the models generally are only able to account for a fraction of uncertainties (*Figure 1*). In the Indian ocean case study that is used here for illustration, nine sources of uncertainties were consid-

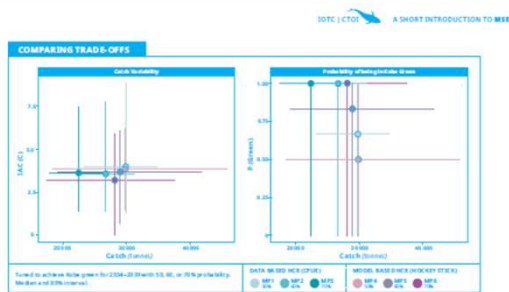


Figure 8. Pairwise trade-offs, between Catch/Catch Variability (left) and Catch/Safety (right).

available to the management procedure should have an equivalent in the real world, for example, a particular CPUE index or a fisheries independent survey. Simulations can help identify biases in our perception of

management's success and tell us how these biases depend on the quality/quantity of data and/or on the simplifying assumptions we make in the estimating model.

Table 1. Performance of six MPs measured by five statistics. The MPs are sorted by tuning level. Darker shading represents better performance, however, the boundaries which determine shading are arbitrary. Moreover, cell colour coding creates a false sense of comparability between categories that are valued differently by different stakeholders.

Harvest Control Rule (HCR)	Tuning Level	Management Procedure (MP)	Performance Measure (median values)				
			SSB/SSB _{MSY}	Probability Kobe Green	Proportion of simulations (SSB > 20% of B0) (overfished)	Catch (tonnes)	Catch variability (CV)
CPUE	50%	MP1	1.13	67%	63%	29500	3.99
		MP4	1.10	50%	69%	29500	3.84
CPUE	60%	MP2	1.27	100%	71%	26800	3.58
		MP5	1.23	83%	79%	29000	3.65
CPUE	70%	MP3	1.47	100%	80%	22500	3.68
		MP6	1.36	100%	89%	28200	3.21

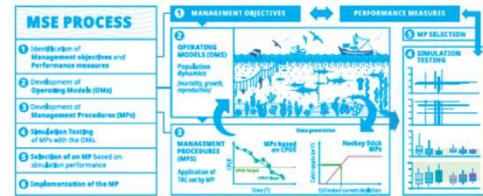


Figure 9. MSE framework

IN SUMMARY

MSE enables exploring a wider set of questions than traditional stock assessments and facilitates agreeing on management procedures that are robust to a wider range of uncertainties than previous management regimes, in commercial or industrial fisheries.

MSE approaches necessitate resolution of a variety of scientific disputes, which itself can be a benefit. It can show that some of the uncertainties that have been considered important are in fact unlikely to have impacts on management objectives, thus lessening conflicts and resolving differences in beliefs.

Other philosophical questions remain open. How to decide on the plausibility of operating models is still an active area of research. Should operating models have predictive powers? How should they be validated and how often? When can we say that MPs have been sufficiently tested and who gets to say it?

How can we deal with the barriers to participation presented by the technical nature of the MSE approach? Open source approaches to sharing the code are helpful but do not empower key stakeholders to critically engage with the process. Reproducibility is an issue even for other modelers; results are rarely run by more than one team.

While helpful in resolving some disagreements, MSE rarely addresses questions of equity. Harvest control rules that are evaluated within MSE usually say little or nothing about how the total catch should be allocated among different users of the resource. However, there have been examples where MSE was explicitly designed to tackle these issues.

The socio-economic benefits of MSE are not guaranteed but depend strongly on how the MSE process is set up, especially, on its transparency, inclusiveness, and effort to improve communication.

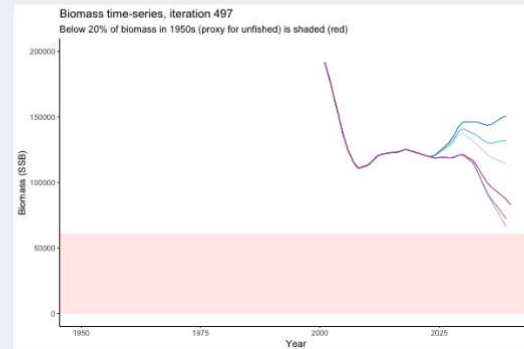
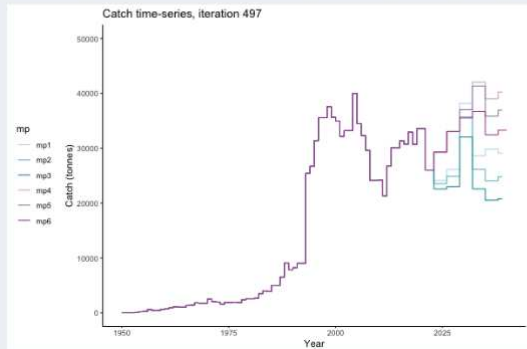
For further explorations, visit the MSE Shiny app and Website created by IOTC.

MSE Capacity Building Tools
[IOTC Shiny app](#)

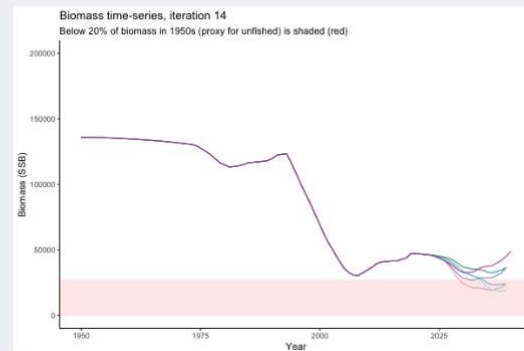
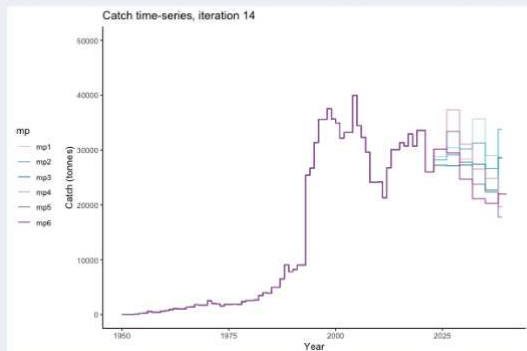
MSE Tool Website
iotc.org/educational-tools

Looking at random individual trajectories is a good way to communicate volatility over time. Here we explore what happens in the same world under different MPs and get a sense of how tuning works. All MPs set TAC for 3 years at a time, no implementation error (e.g. it is assumed that TAC equals actual catch) and the maximum change allowed is 15% of previous TAC - thus the step function visualisation is more appropriate for catch.

In this random simulation where it seems that if you want the highest catch (left), you should select MP4 (light pink).



However, looking at a different random simulation, below, MP4 appears as one of your worst options in terms of catch.



Purposes

- to understand the **expected behavior of “MPs”** if implementing them in an actual fishery
- to find the best way by developing MPs to **robustly meet the pre-determined management objectives** (acceptable trade-off and levels of risk)
- to **select an MP** for implementation in actual fisheries

Merits of MSE

- **Comprehensiveness, Transparency and Dialogue**
- Consider in advance **uncertainty** in data, model, estimation, projection, implementation etc.
- Ensure a certain level of **robustness** of management performance to uncertainty
- Information is available in advance for some **likely trajectories** and their ranges for biomass, catch, etc. after implementing an MP

- IOTC MSE handbook
- IOTC web tool
- 2024: MSE Capacity building workshop in Maldives
- 2025: Capacity building on MSE prior to WPTT(AS) in Seychelles





**THANK YOU SO MUCH
FOR KIND ATTENTION**

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