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MANAGEMENT STRATEGY EVALUATION INTRODUCTION

TOSHIHIDE KITAKADO, IOTC-SC-CHAIR

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MSE IN NUTSHELL (CONCEPTUALLY)

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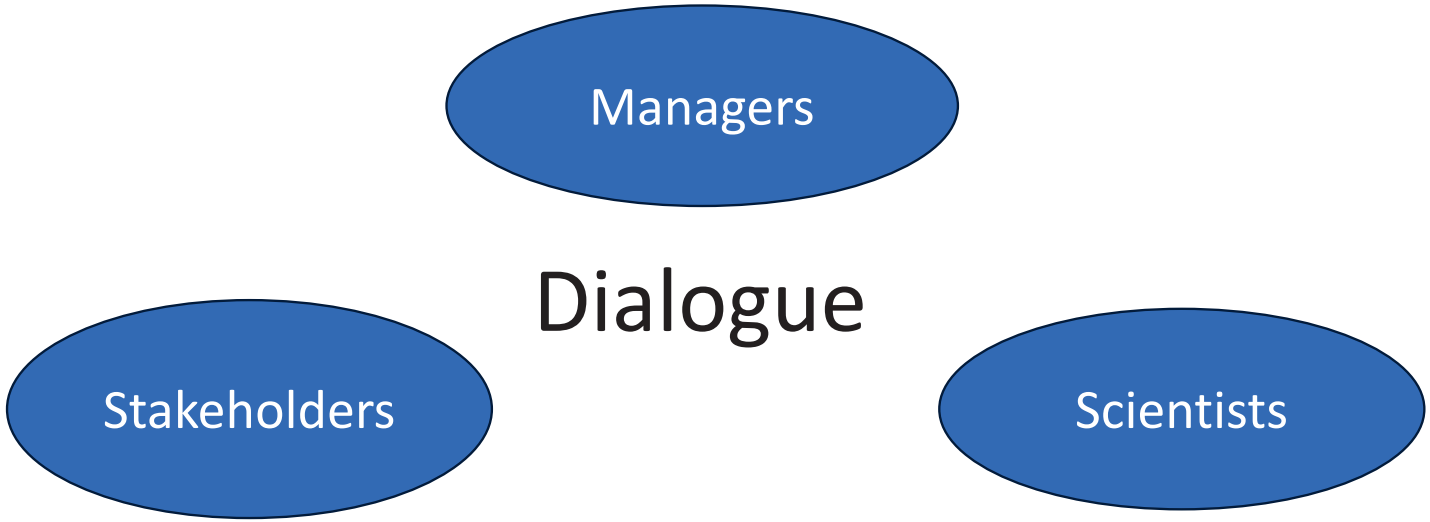
Simply…. Management Procedure (MP) is

"a pre-defined rule to set a TAC "

Simply…. MSE is

"an evaluation process of candidate management procedures for achieving stated management objectives through stochastic simulations" (DS Butterworth)



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SETTING TAC BASED ON STOCK ASSESSMENT

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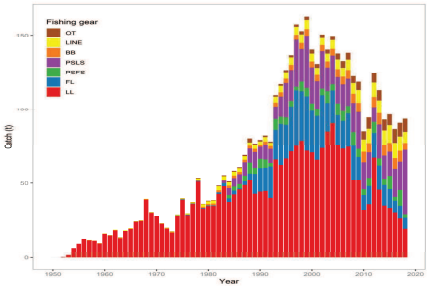
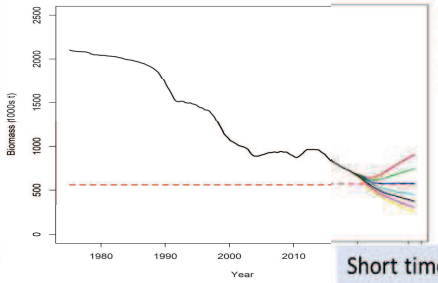
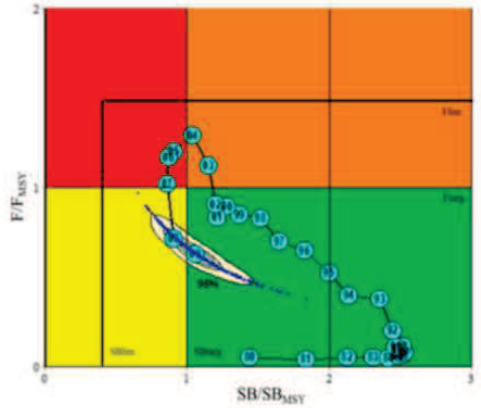
Stock assessment with constant catch projection approach

Data → Assessment → Projection → Discussion → TAC







EXAMPLE 2: Species: Aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based reference points for nine constant catch projections (average catch level from YYYY–YYYY (xx,xxx t), ± 10%, ± 20%, ± 30% and ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe		Alternative catch projections (relative to the average catch level from YYYY–YYYY) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)								
		60% (catch t)	70% (catch t)	80% (catch t)	90% (catch t)	100% (catch t)	110% (catch t)	120% (catch t)	130% (catch t)	140% (catch t)
Short time frame (3rys)	$B_{2016} < B_{MSY}$	9	13	19	28	40	53	65	82	86
	$F_{2016} > F_{MSY}$	3	6	30	56	81	91	98	99	100
Mid time frame (10yrs)	$B_{2023} < B_{MSY}$	0	0	1	3	14	41	87	100	100
	$F_{2023} > F_{MSY}$	0	0	5	67	92	98	99	100	100

Reference point and projection timeframe		Alternative catch projections (relative to the average catch level from YYYY–YYYY) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.4\ B_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)								
		60% (catch t)	70% (catch t)	80% (catch t)	90% (catch t)	100% (catch t)	110% (catch t)	120% (catch t)	130% (catch t)	140% (catch t)
	$B_{2016} < B_{Lim}$	4	6	8	14	20	23	40	45	65
	$F_{2016} > F_{Lim}$	3	6	15	15	20	33	45	67	100
	$B_{2023} < B_{Lim}$	0	0	0	6	24	26	49	74	100
	$F_{2023} > F_{Lim}$	0	0	0	10	22	45	67	96	100

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Management procedure (MP)

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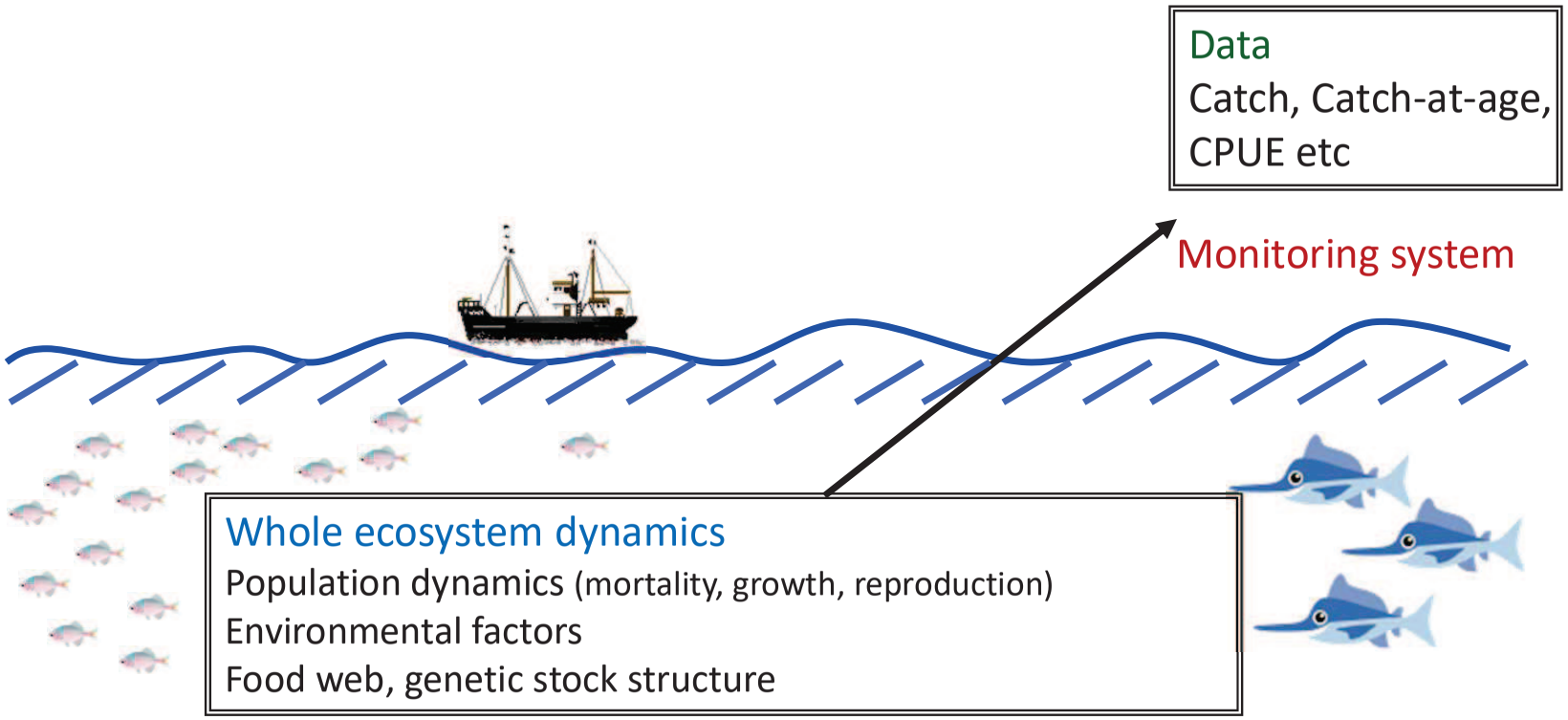

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Management procedure (MP)

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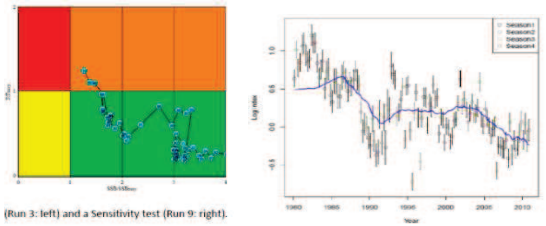
Total Allowable Catch (TAC)



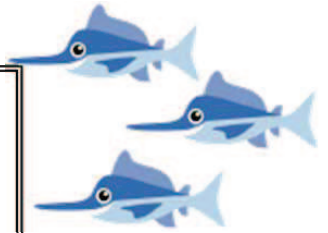
(Run 3: left) and a Sensitivity test (Run 9: right).

Harvest Control Rule (HCR)

Stock assessment, Model development Parameter update

Data
Catch, Catch-at-age, CPUE etc

Monitoring system



Whole ecosystem dynamics
Population dynamics (mortality, growth, reproduction)
Environmental factors
Food web, genetic stock structure

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Management procedure (MP)

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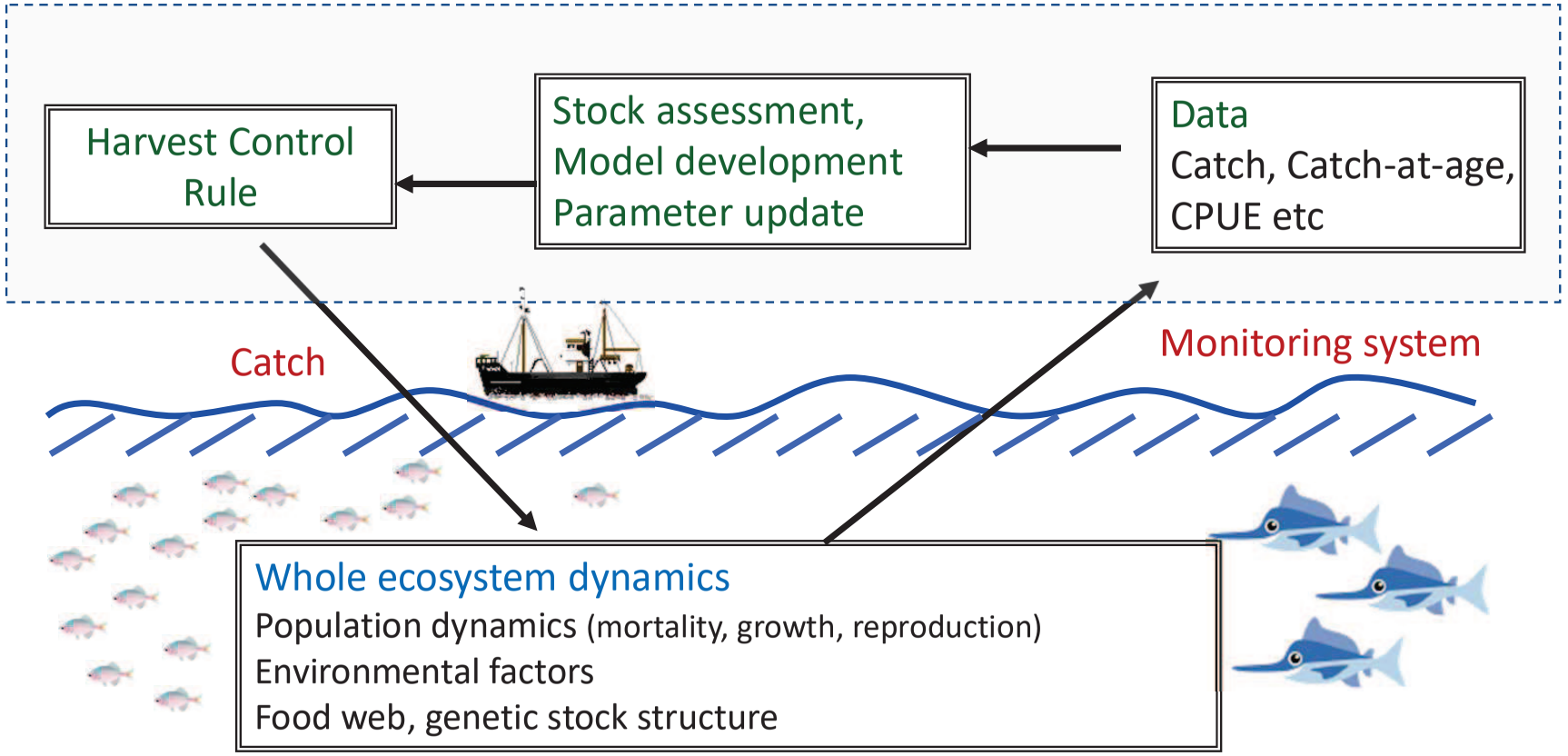
Management Procedure



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SETTING TAC

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Stock assessment with constant catch projection approach

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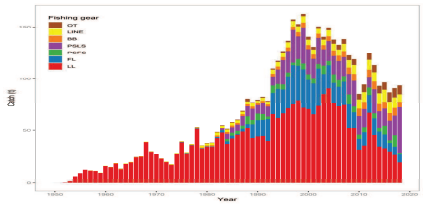

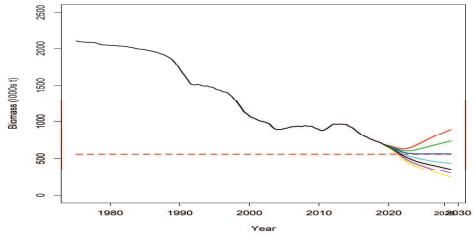

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$B_{2016} < B_{MSY}$	9	13	19	28	40	53	65	82	86
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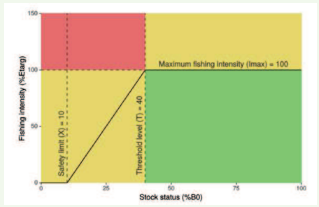
Pre-determined management procedure

Data → Assessment (if needed) → HCR or pre-determined rule → TAC



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MSE IN NUTSHELL

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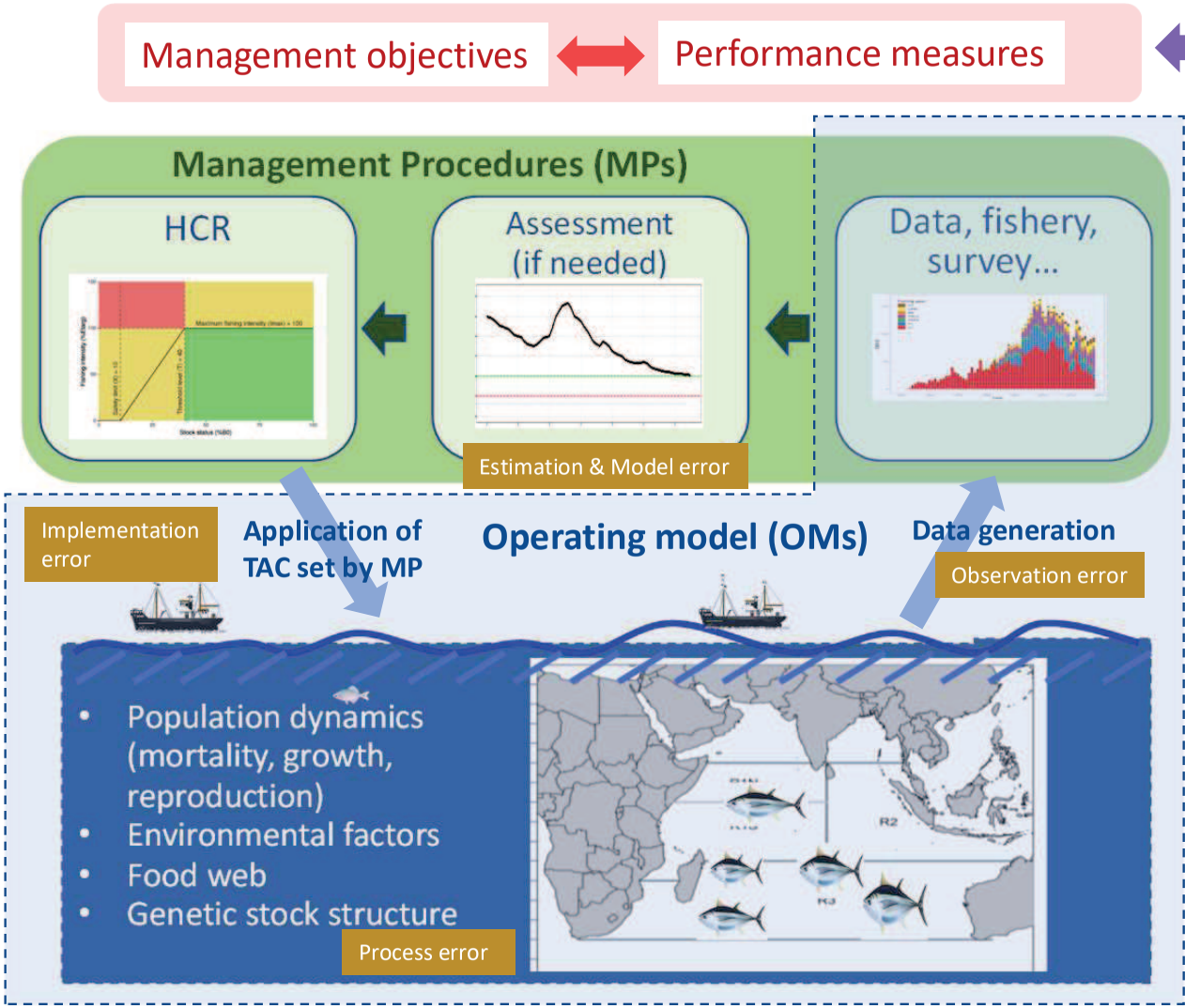
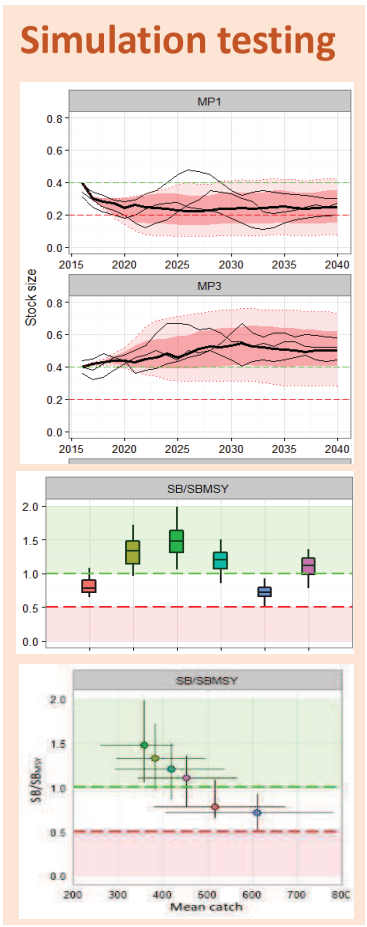
MSE Process

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 concept mapping : Simulation evaluation of Candidate Management Procedures (CMPs)

Operating models(OMs)

- True virtual population in computer
- True virtual fisheries in computer
- Several uncertainties

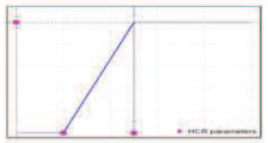
Condit ioning

Learn population dynamics and impact of fisheries from past data (normally stock assessment + a)

CMPs = Predetermined rules to set TAC

Sequentially generate future data (e.g. CPUE) used in MP, reflecting to fisheries impact

Apply CMPs to data generated from OMs



Test use of CMPs in simulation

Repeat next [e.g. 15] yrs [e.g. 1000] times over [e.g. 36] models

Summary of simulation with OMs & CMPs

Management period (time frame)

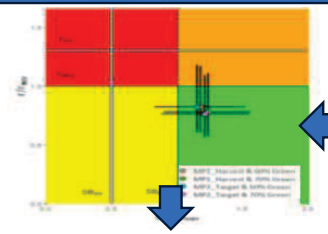
Stochastic uncertainty in data & population

Uncertainties in model & parameters

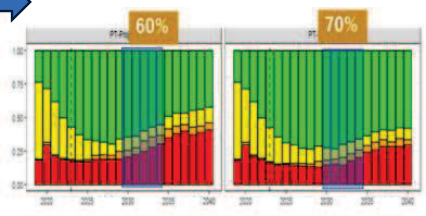
Setting tuning criteria

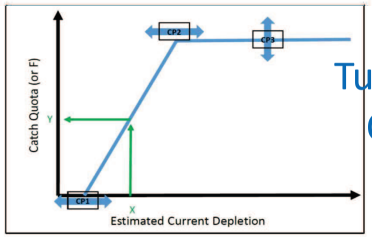
Key objectives

- Stock status & safety
- Catch performance
- Several indicators (Target/Limit RPs) Probs Kobe quadrant

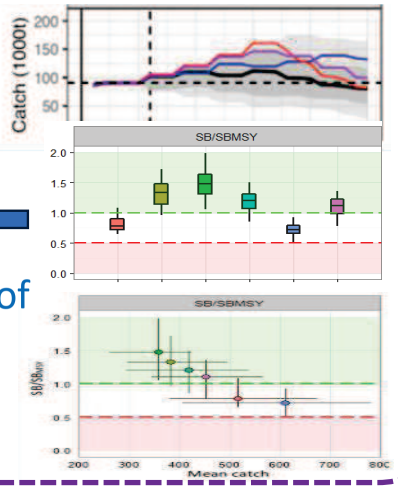


Evaluation & selection of an MP

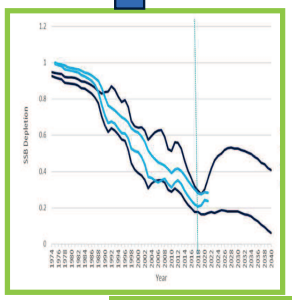




Tuning of CMPs

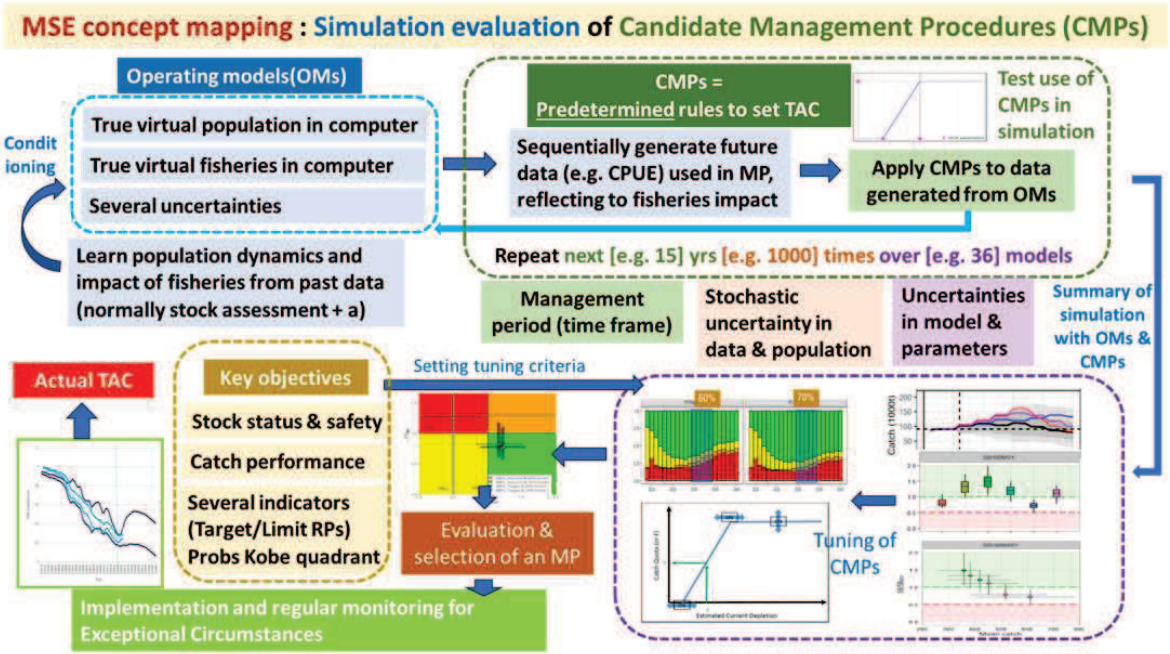


Actual TAC



Implementation and regular monitoring for Exceptional Circumstances

If you have any suggestions to improve my mapping or criticisms of it, that's a sure sign you have a strong understanding of MSE! Please advise me! (but later)



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KEY WORDS AND CONCEPTS

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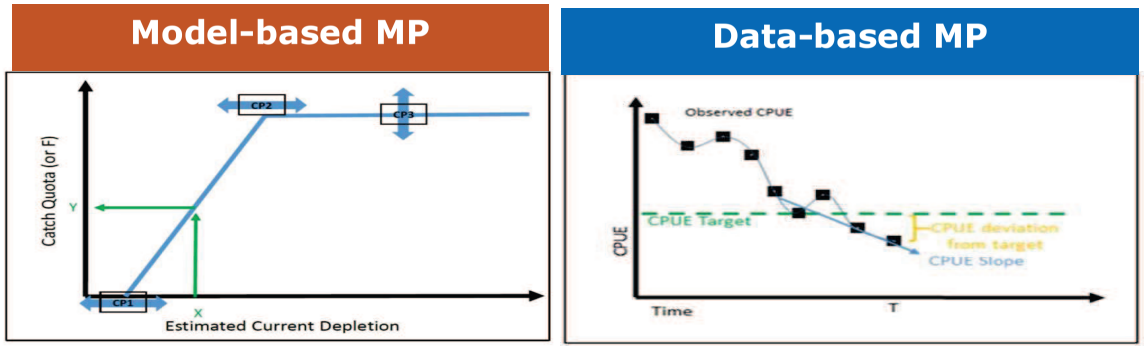
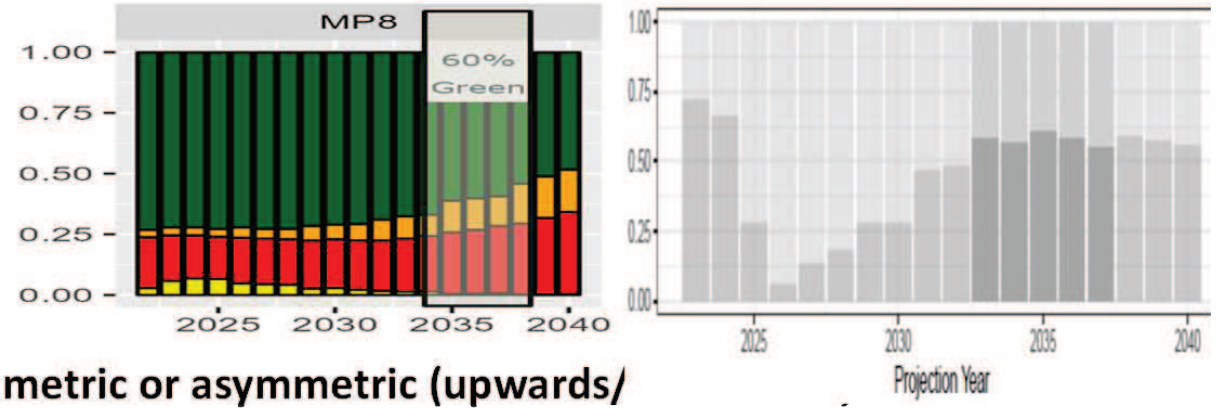
- Operating Models (OMs)
- Type of management procedures (MPs)
  - Model-based (Assessment & Harvest Control Rule(HCR))
  - Data-based (CPUE trend or CPUE-based HCR)



- Tuning criteria
  - Tuning a parameter of MPs associated with the management goals
  - Kobe green quadrant probability (50, 60 and 70%) etc. in a certain window



- Other important elements
  - Constraints (maximum change in TAC): symmetric or asymmetric (upwards/
  - Time lag: 2-3 yrs ("data-lag" + "implementation lag")
  - Robustness scenarios (implementation error, recruitment failure etc.)
  - Regular check for Exceptional Circumstances

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MSE IN NUTSHELL (1) MANAGEMENT OBJECTIVES

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MSE Process

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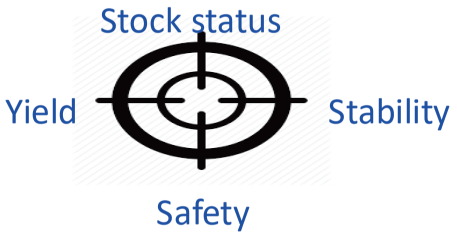
6. **Implementation of the MP**

- Several different objectives
- Use of performance measures to see if management objectives are met or not

Management objectives ⇔ Performance indicators

Stock status	⇔	Probability that stock is being above a target level
Safety	⇔	Probability that stock is breaching the biomass limit
Yield	⇔	Maximize average catch over management period
Stability	⇔	Minimize the yearly variation



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MSE IN NUTSHELL (2) MANAGEMENT PROCEDURES (MPS)

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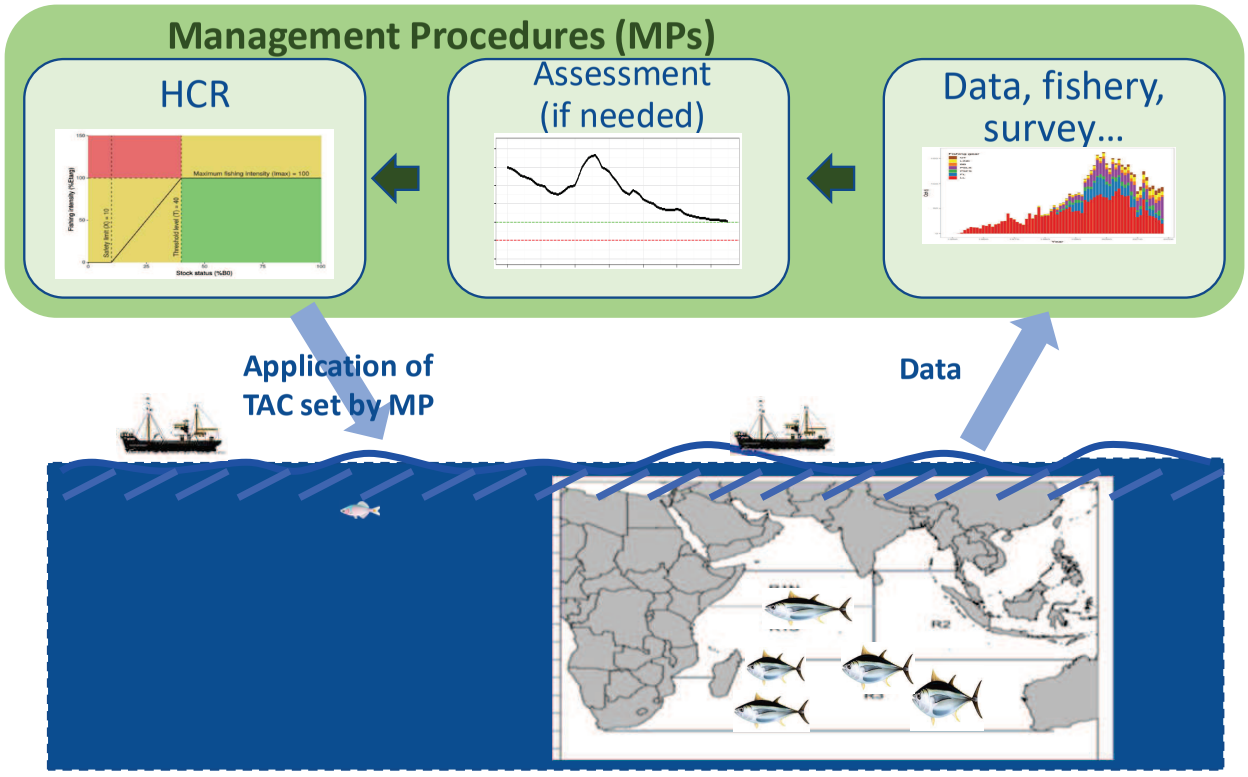
"Management Procedure (MP)": a predetermined rule to set a TAC



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MSE IN NUTSHELL (2) MANAGEMENT PROCEDURES (MPS)

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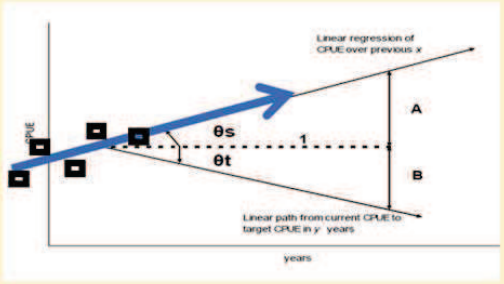
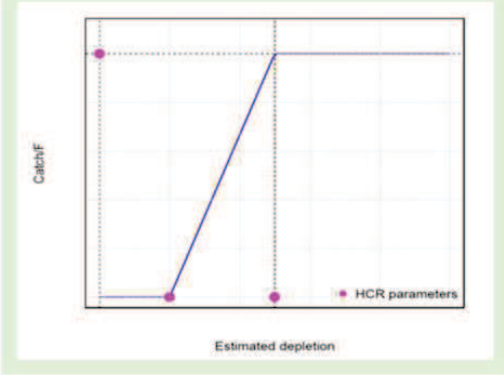
"Management Procedure (MP)": a predetermined rule to set a TAC

Empirical (model-free, CPUE-based)



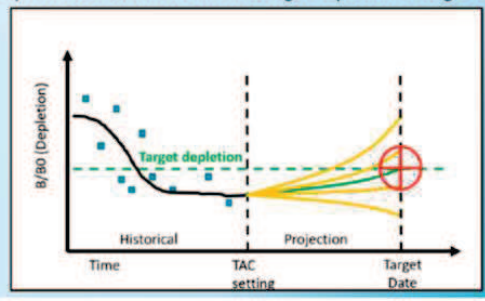
Model-based with simple stock assessment



Model-based MP with internal projection

PTRE-based MP with internal projection

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



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MSE IN NUTSHELL (3) OPERATING MODELS (OMS)

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MSE Process

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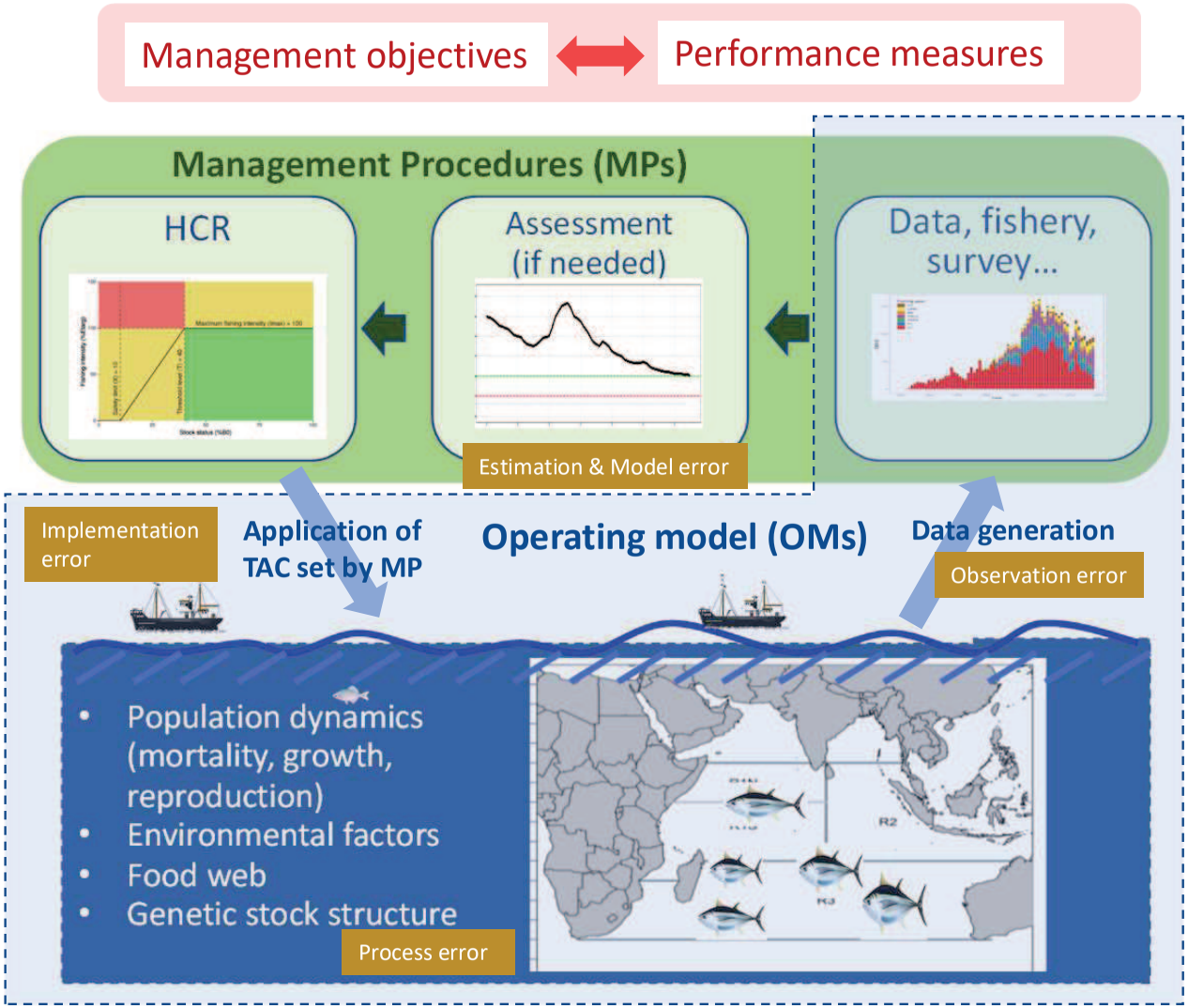

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MSE IN NUTSHELL (3) OPERATING MODELS (OMS)

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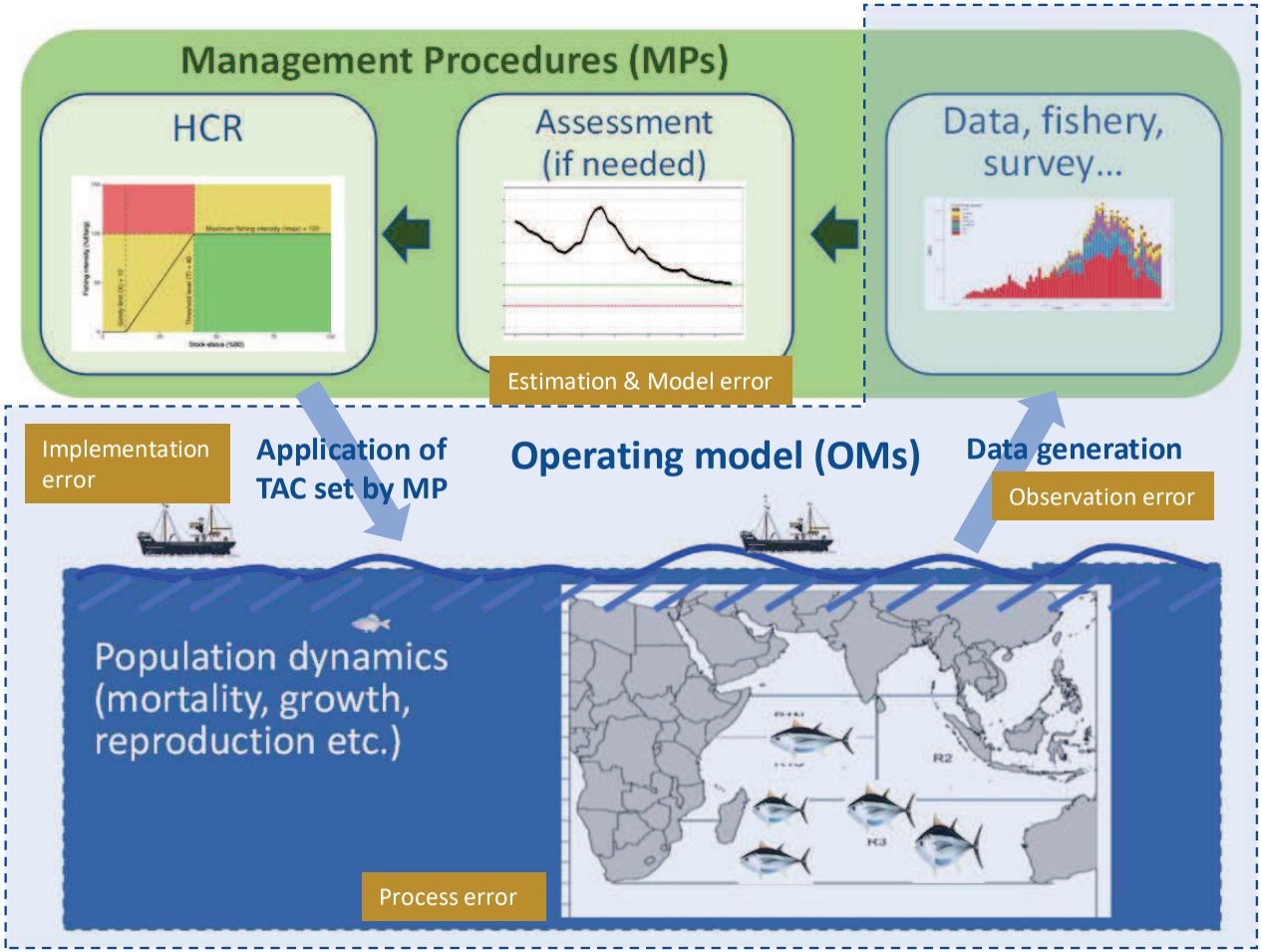
For testing MPs, we need **"virtual population"** and **"virtual fishery following an MP"**

⇒ **Operating models (OMs)**



- OMs generate data used in MPs
- OMs can account for the impact of catch on the stock
- OMs are primarily based on the stock assessment, but should not be completely equal to the assessment models
- Consider several key uncertainties in parameters, and other kinds of uncertainties to evaluate the **robustness** of candidate Management Procedures

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MSE IN NUTSHELL (3) OPERATING MODELS (OMS)

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For testing MPs, we need **"virtual population"** and **"virtual fishery following an MP"**

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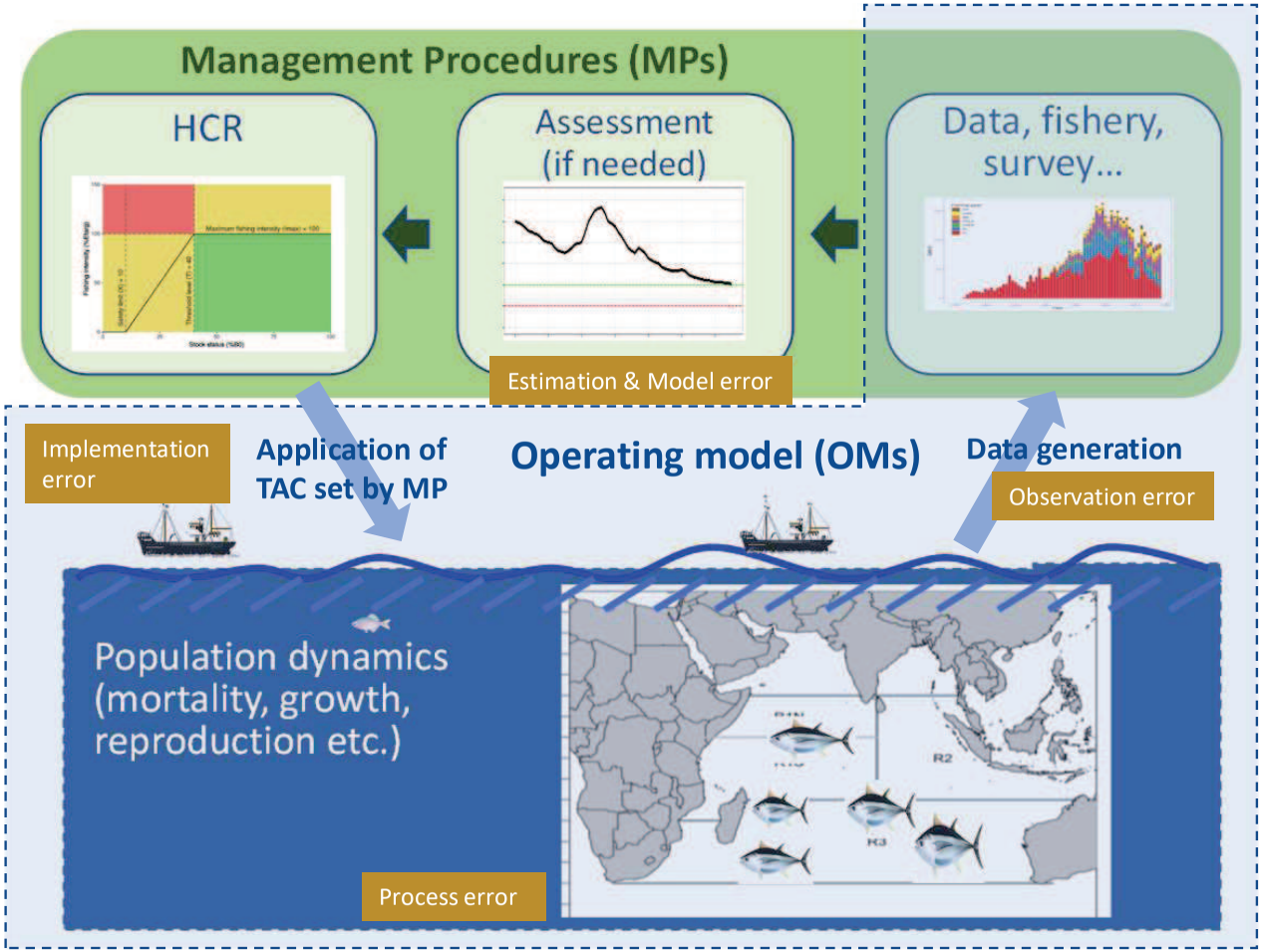

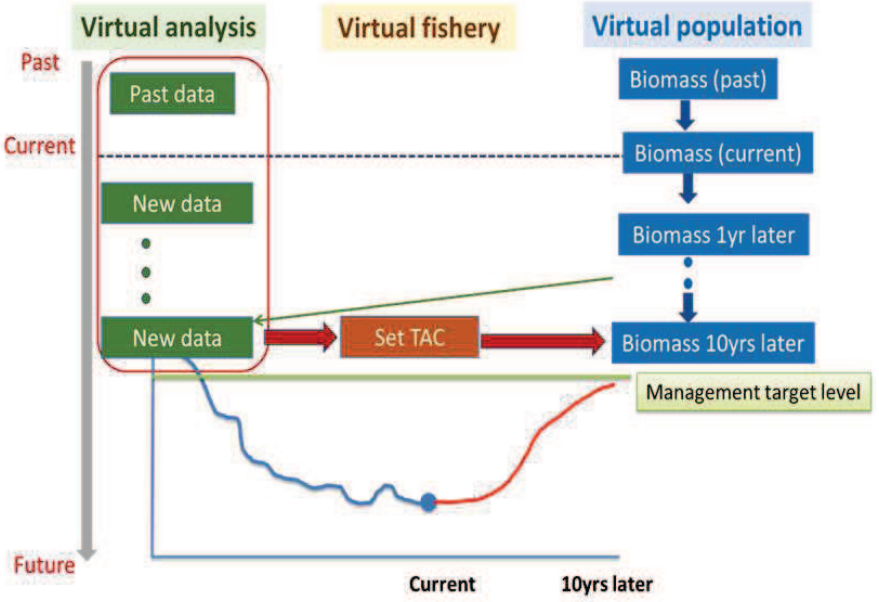

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MSE IN NUTSHELL (3) OPERATING MODELS (OMS)

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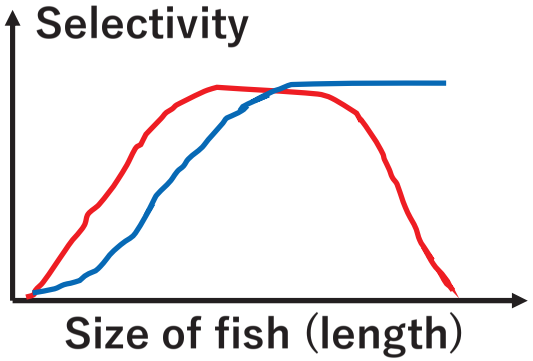
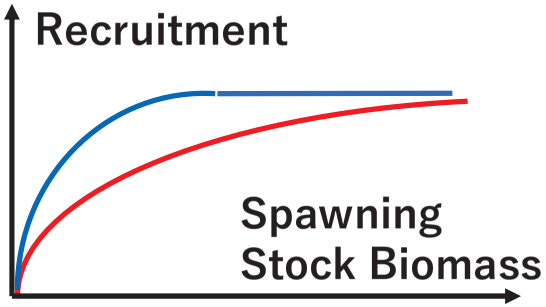
Reference cases

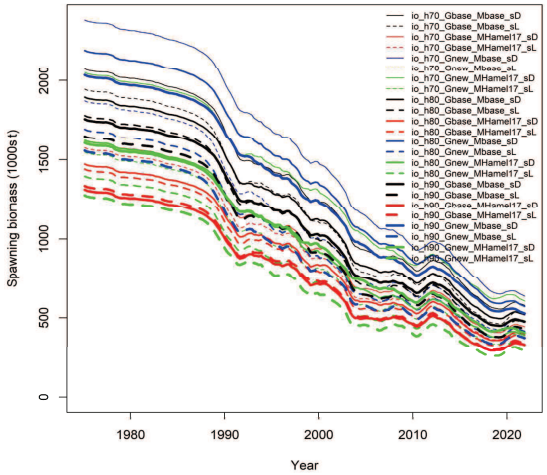
- Steepness in stock-recruitment relationship
- Natural mortality
- Growth + maturity
- Size selectivity
- Catchability
- …

Robustness cases

- More uncertainty in CPUE (input)
- Over catch
  - Accurate reporting (better)
  - Some unreported catch
  - Unreported (worst)
- Catchability further up
- Recruitment shock …







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SEVERAL MODELS

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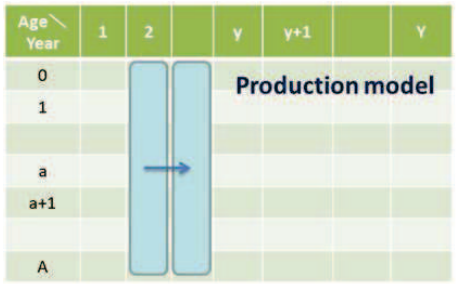
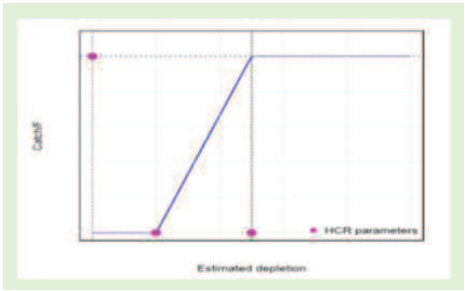
Models for assessment within MPs

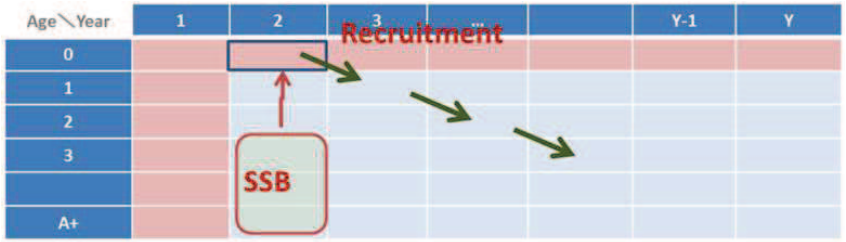
Simpler assessment models to give **robust input on stock status** to HCR

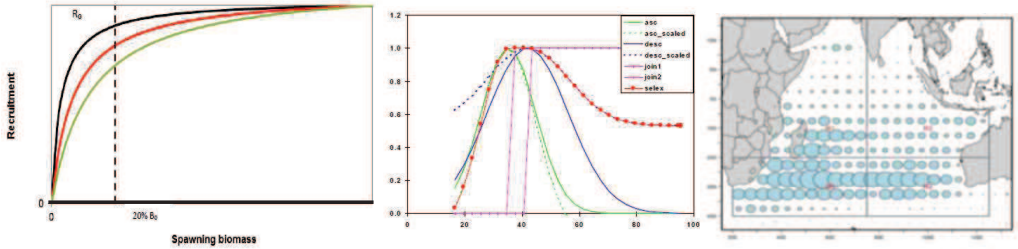


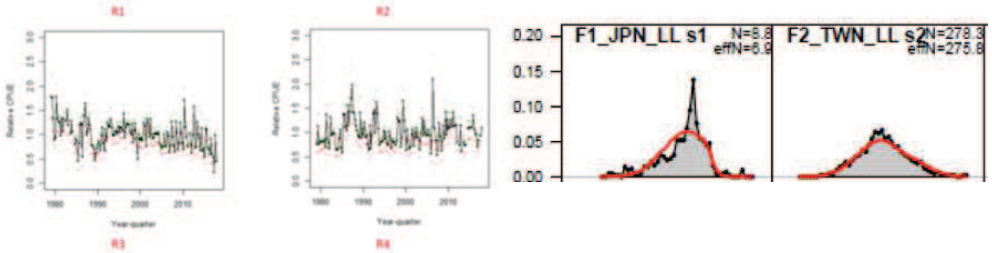


Models for stock assessment

Stock status, benchmark, detailed mechanism and life history (by age/life stage and by gear/space/time)







Operating Models (OMs) in MSE

To play roles of **"virtual population dynamics"** and **"virtual fishery"** in the simulation

Primarily based on the stock assessment, but several and broader ranges of uncertainties in key parameters are considered

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MSE IN NUTSHELL (4) SIMULATION TESTING

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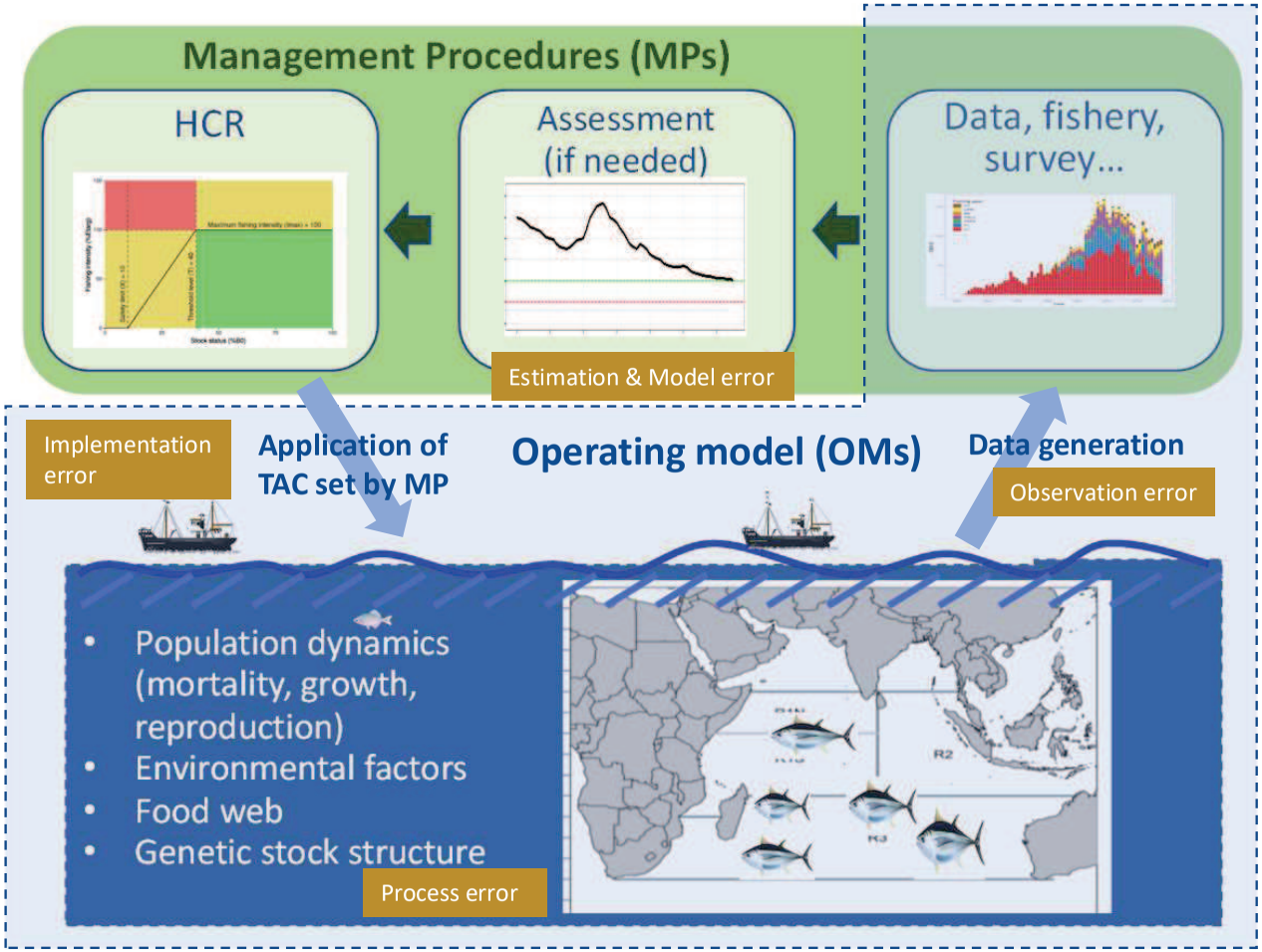
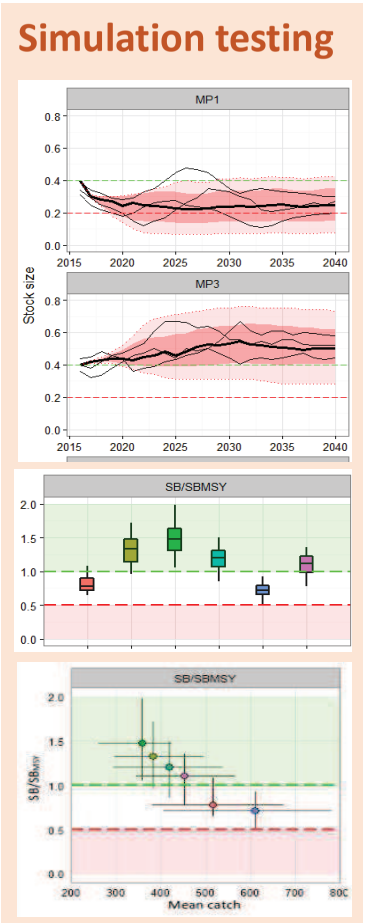
MSE Process

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**

Management objectives ⟷ Performance measures

Selection of an MP





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MSE IN NUTSHELL (4) SIMULATION TESTING

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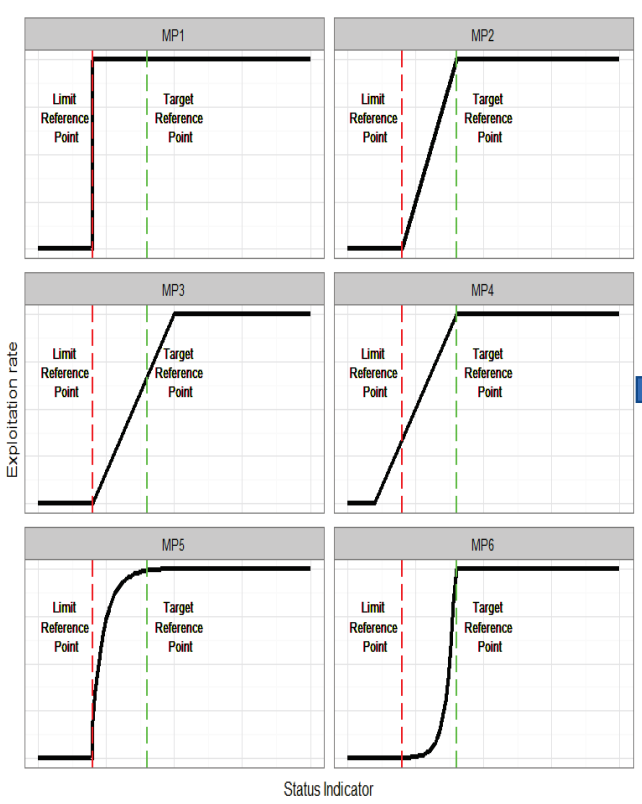
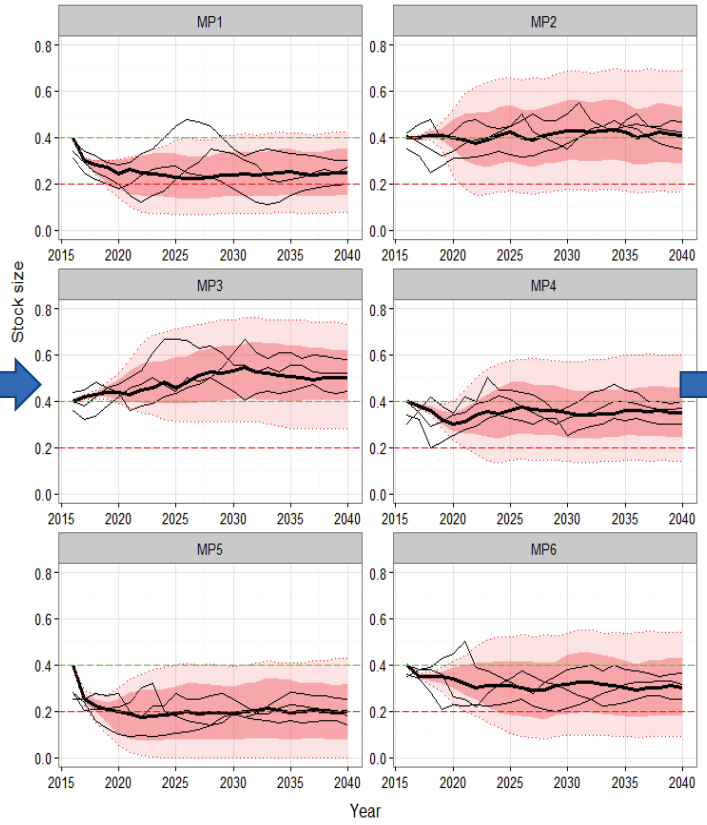
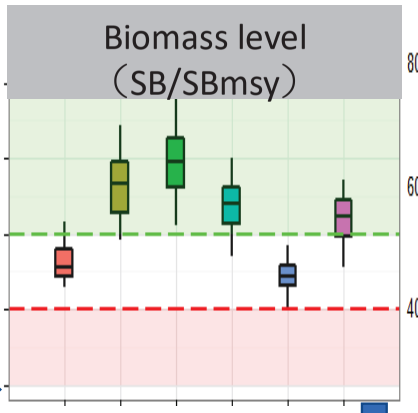
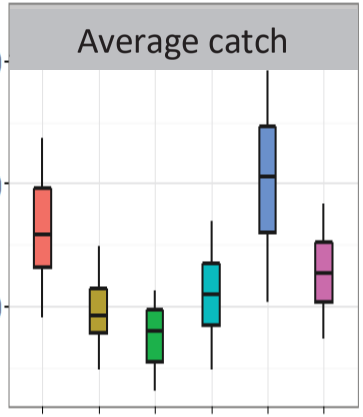
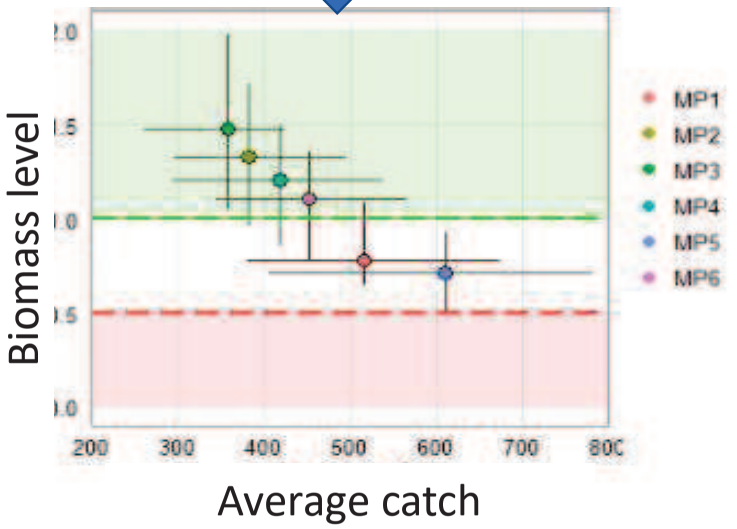
Conduct **comprehensive simulation** to evaluate the performance of MPs using OMs











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BIGEYE TUNA EXAMPLES (TWO-MPS AND 60% & 70% TUNING)

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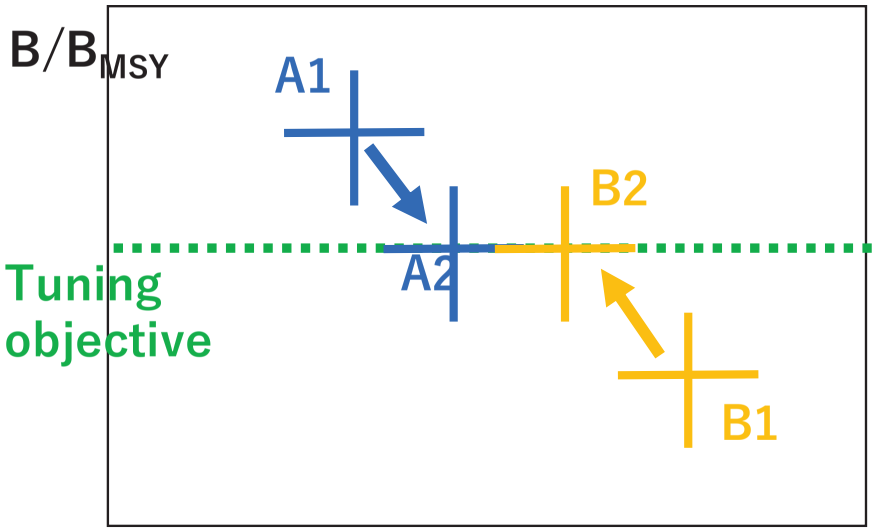

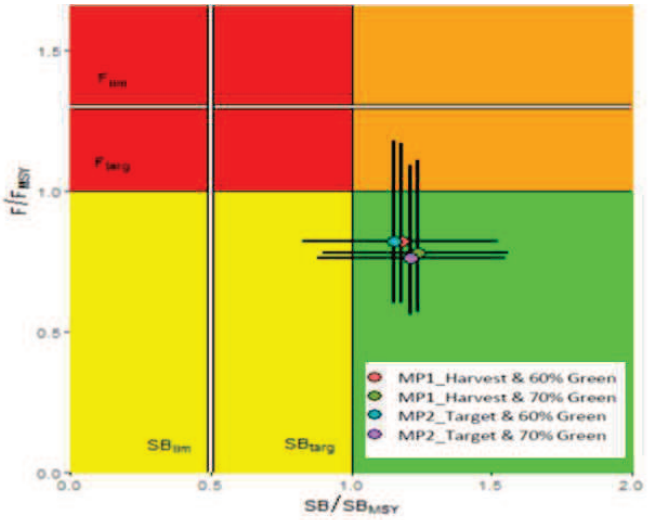

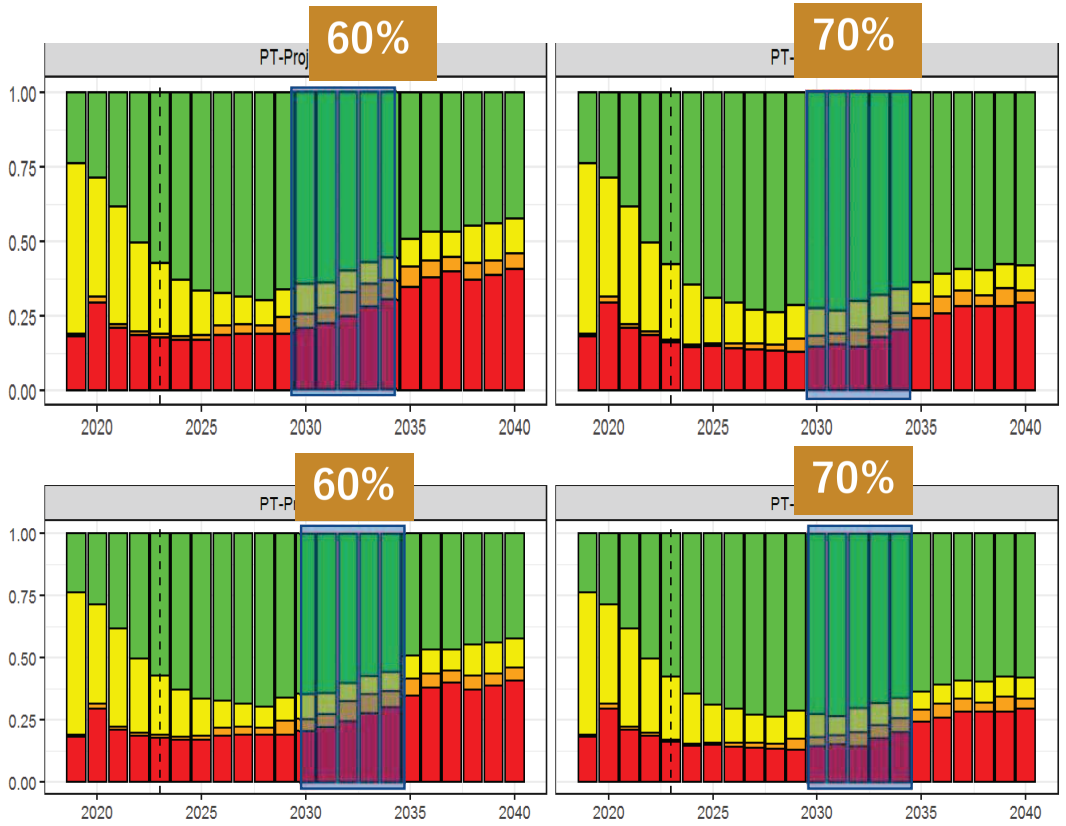

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SELECTION OF MPS

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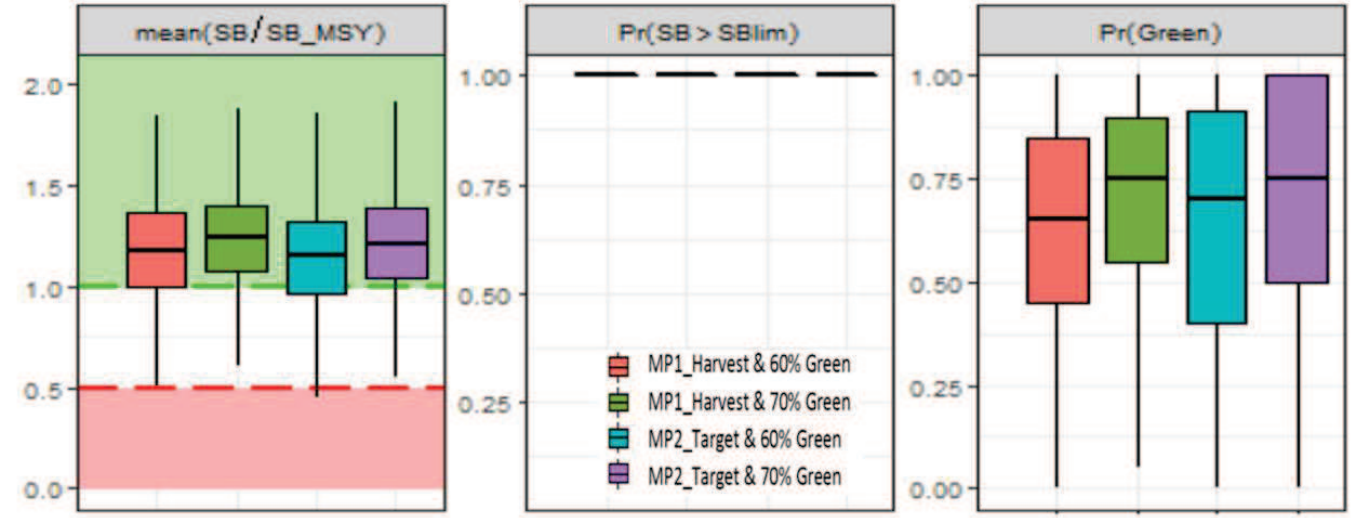

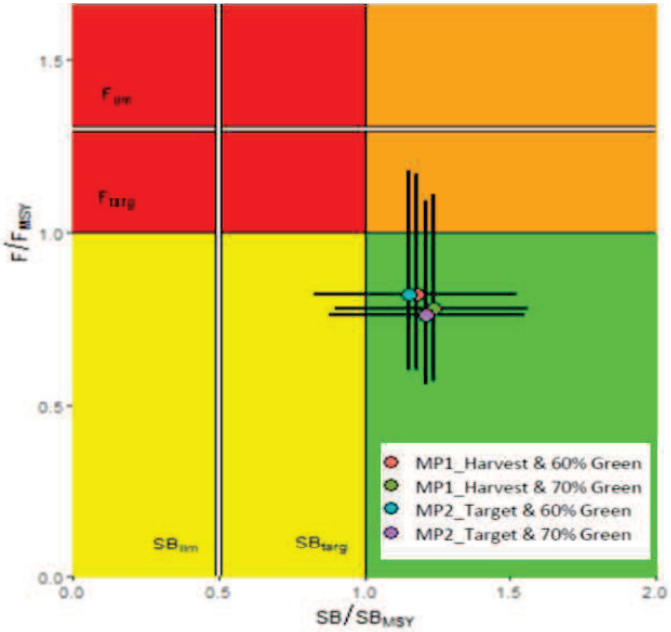

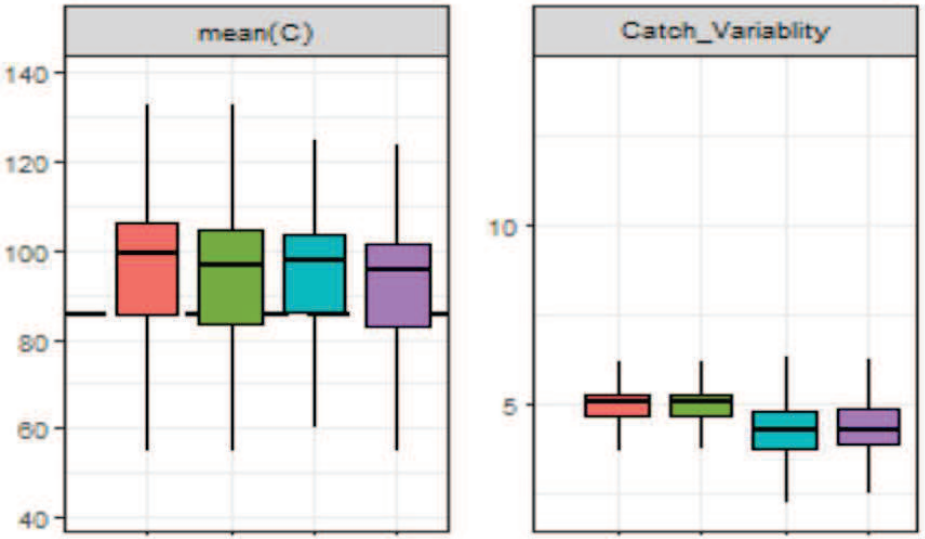

	Performance Measure				
MP	SB/SB_{MSY}	Prob(Green)	Prob(SB>limit)	Mean Catch (t)	Catch Variability (%)
MP1_Harvest 60% Green	1.18 (1.00-1.36)	0.63	0.97	99.3 (85.6-106.1)	5.06
MP2_Target 60% Green	1.15 (0.96-1.32)	0.63	0.97	97.7 (86.0-103.6)	4.23
MP1_Harvest 70% Green	1.24 (1.07-1.40)	0.69	0.98	96.6 (83.7-104.6)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

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MSE: “Meta-rules” higher level oversight MP-based management

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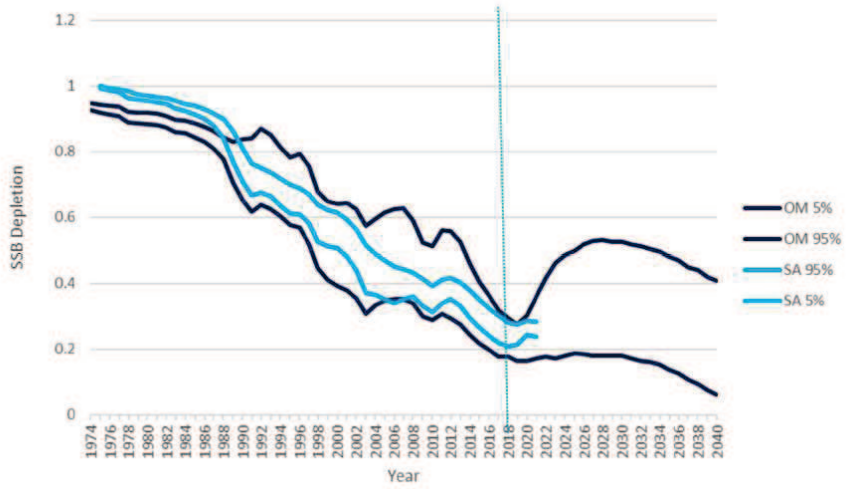
- **Need “regular monitoring” for MP implementation**
- **Need “regular review” of MSE**
- **Need safeguard for “Exceptional Circumstances”**
  - New information: out of range of previous knowledge
  - Input data for MP: missing (no longer available), historically changed etc.
  - Inconsistency between TAC recommended and actual catch
  - Rare events, when the fishery system falls outside of the scope of the simulation testing, e.g. recruitment failures



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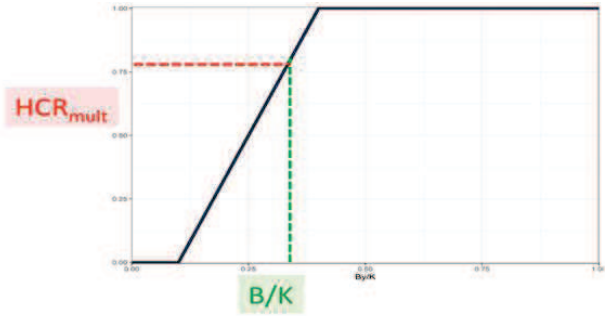
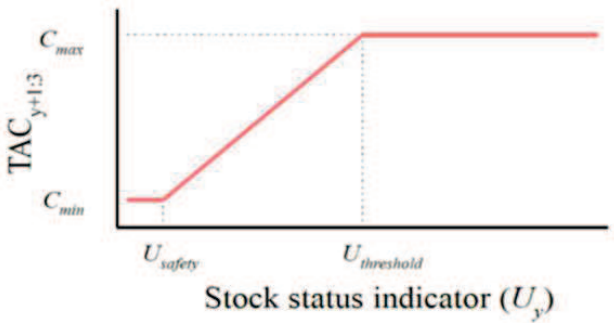
CURRENT MPS

	Bigeye	Skipjack	Swordfish
Stock status	2022	2023	2023
CMM/Prop	22/03 (MP), 23/04 (Catch limits)	24/07 (MP)	24/08 (MP)
Tuning criterion	Prob(Kobe G) ~~= 50%,~~ 60%, 70%	Prob(B>B40% & E<E40%) ~~=~~ 50%, 60%, 70%	Prob(Kobe Green) ~~= 50%,~~ 60%, 70%
MP type	~~•Data-based~~ Model-based (MP1-Harvest MP2-Target)	•Data-based (stable) •Data-based (target) ~~•Model-based~~	•Data-based (fast) •Data-based (slow) •Model-based
Constraints etc.	15% maximum change	•Symmetric 15% max change •Asymmetric 15%(up)-10% (down)	Asymmetric 15% (up) - 10% (down)

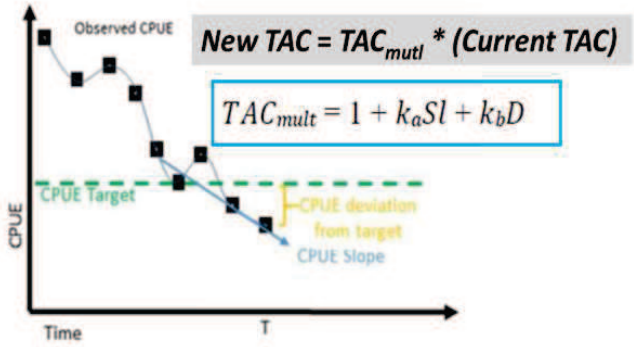
Fishing intensity is controlled to set a TAC depending on stock status based on an internal simple assessment



TAC is directly controlled depending on stock status indicator (CPUE)



TAC is updated by CPUE trend and its difference against target



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SCHEDULE

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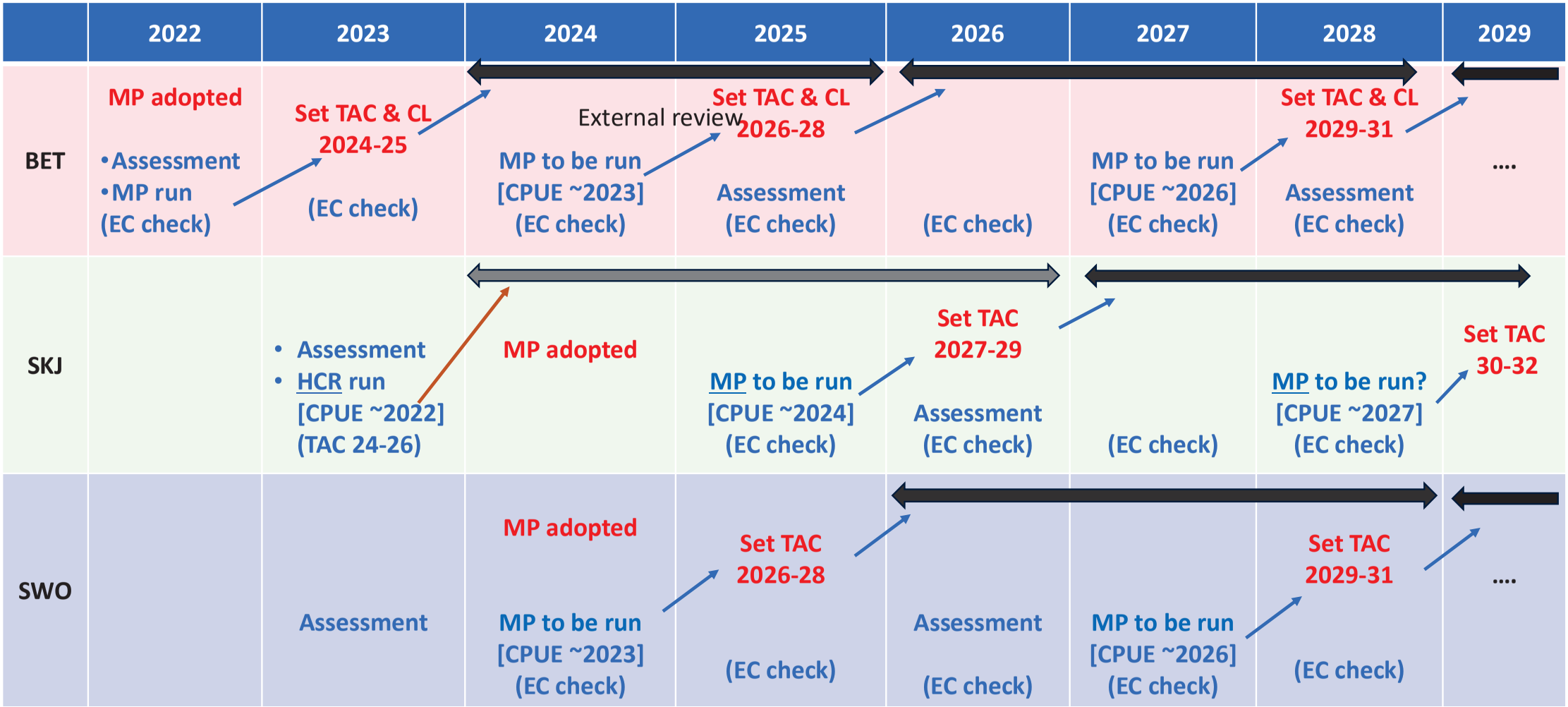

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SUMMARY OF MSE

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The MSE is a computer simulation framework (actually 30 years history)

- 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

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USEFUL RESOURCES IN IOTC (HANDBOOK)

iotc ctoi

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-

INDIAN OCEAN Tuna Commission

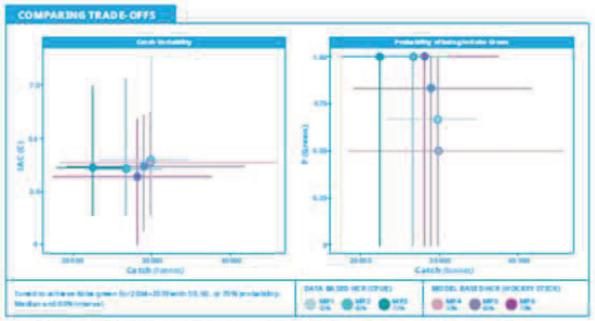

Figure 8. Pairwise trade-offs, between Catch/Catch Variability (left) and Catch/Safety (right).

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, quilt 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 SSB0 (unfished)	Catch (tonnes)	Catch variability (AAC)
CPUE	50%	MP1	1.13	67%	63%	29900	3.99
Hockey Stick		MP4	1.10	50%	69%	29900	3.84
CPUE	60%	MP2	1.27	100%	71%	26800	3.58
Hockey Stick		MP5	1.23	83%	78%	29000	3.65
CPUE	70%	MP3	1.47	100%	80%	22500	3.68
Hockey Stick		MP6	1.36	100%	89%	28200	3.21

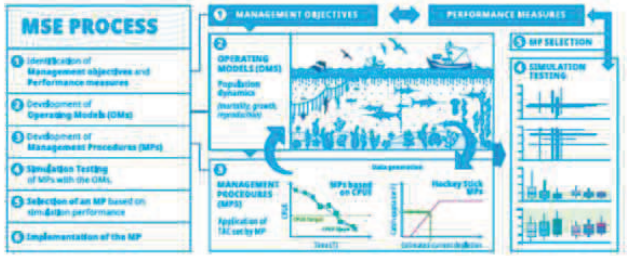

Figure 9. MSE framework

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 modellers; 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

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USEFUL RESOURCES IN IOTC (SHINY APPLICATION)

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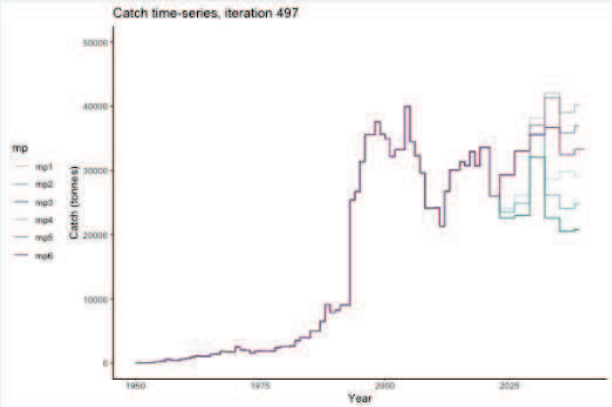
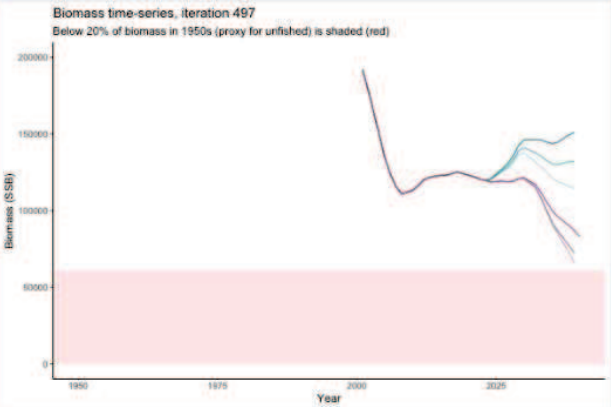
Looking at **random individual trajectories** is a good way to communicate volatility over time. Here we explore what happens in the same world under different MPs and get a sense of how tuning works. All MPs set TAC for 3 years at a time, **no implementation error** *(e.g. it is assumed that TAC equals 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.