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Bonus Lecture

"Overview of Management Strategy Evaluation"

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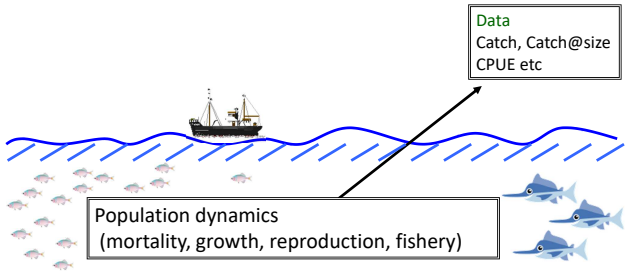
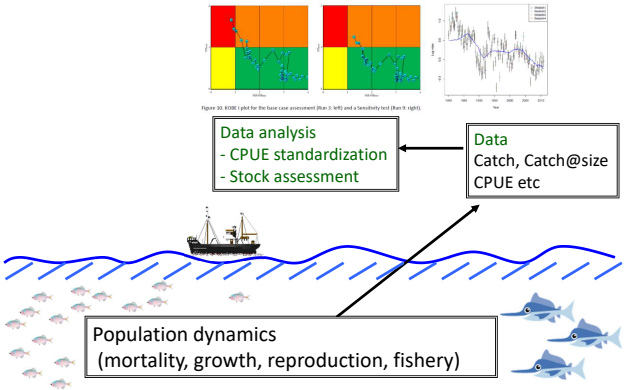
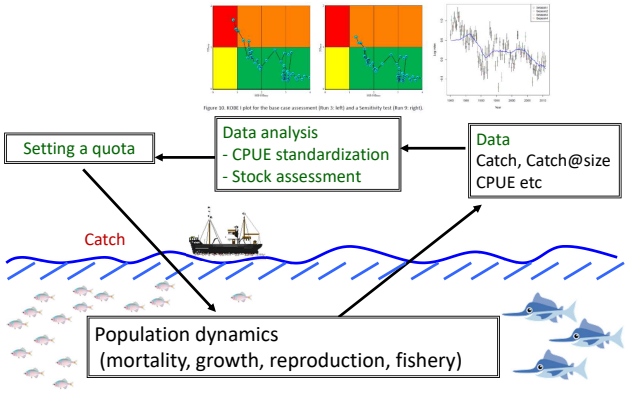
## MSE in nutshell




## MSE in nutshell

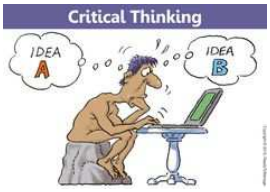



## MSE in nutshell




## Why MSE?

- Imagine that you are a responsible person to set a fishery quota for next XX years
- You might want to check if a quota set by "you" works or not


## Why MSE ?

- But, how do you set a quota?
- How do you evaluate it?

➡ you need predetermined goals/objectives

## Why MSE?

- How do you set?
- How do you evaluate?

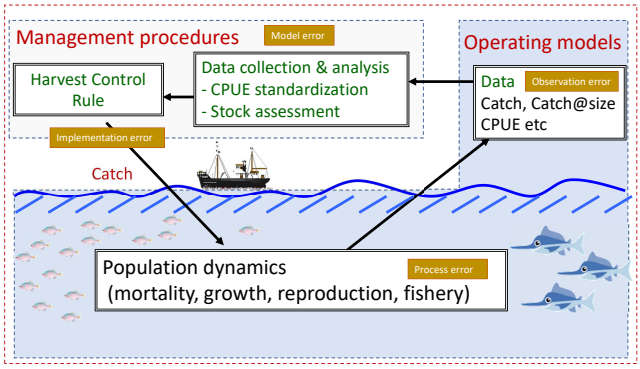
You need predetermined goals/objectives

You need computation for simulation

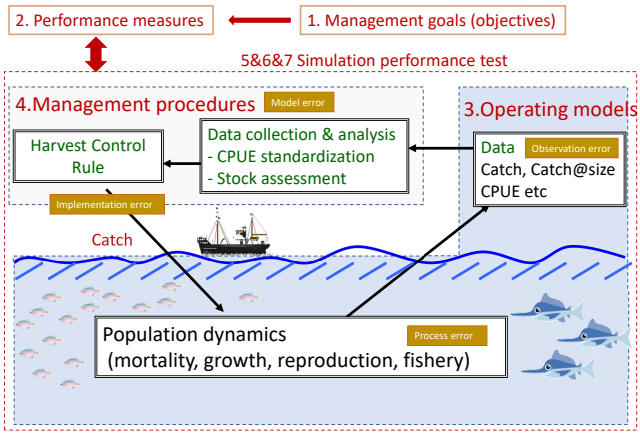

If the quota set by you does not perform adequately under simulation, can we expect it to work in the real world?"

**=> No!**

## MSE in nutshell




## MSE in nutshell




## Process/steps in MSE (not necessarily by this order)

1. Specification and prioritization of management objectives
2. Translation of the management objectives to performance measures and risk indicators
3. Construction of Operating Models (OMs)
4. Development of management procedures (MPs) with harvest control rules (HCRs)
5. Simulation trials
6. Comparison of performance for various MPs
7. Advice of MPs which meet management objectives and select an MP

## Why MSE?

- Framework of "Evaluation of Management Procedures" is not only a computational tool !!
- Rather, a tool to bridge between

| "Stakeholders/decision makers" | "Scientists" |
|---|---|
| ● Identify management objectives<br>● Make potential ideas plausible ways of management and feasibility<br>● Make decisions on the final set of management procedures | ● Translate the management objectives to performance measures and risk indicators<br>● Develop population dynamics with reality<br>● Improve better management procedures to meet the objectives |

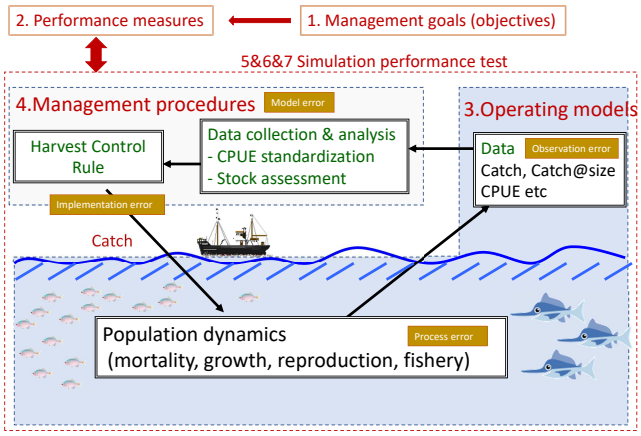
## What is MSE ?

- A simulation framework for assessing the performance of management procedures
- A pioneer work: IWC/SC's RMP
- Since then, the idea has been used and developed for lots of species (not only fishery resources but also terrestrial animals)
- The questions are: if goals/objectives are achieved or not
- Through this process, various sources of uncertainty are taken into account
- Also, adaptive procedures can be incorporated and tested
- Should be practical as much as possible
- Anytime interim, should be reviewed regularly

## What is MSE ?

- Possible to handle various types of uncertainty
  (e.g. Francis & Shotton 1997)
  - Uncertainty in data and input parameters
  - Process uncertainty (e.g. process errors, environmental)
  - Estimation uncertainty (estimation error, SE, CV)
  - Model uncertainty
  - Implementation uncertainty
- Possible to test adaptive management procedures
- Objective and comprehensive evaluation of management procedures and harvest control rules in terms of efficacy, advantage/disadvantage and risks
- Compatible with Ecosystem-based Fishery Management (EBFM)
- Bridge between scientific and social interests

## MSE in nutshell



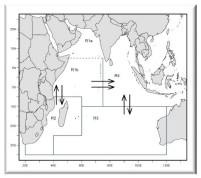

## Process/steps in "Evaluation of MPs"

1. Specification and prioritization of management objectives
2. Translation of the management objectives to performance measures and risk indicators
3. Construction of Operating Models (OMs)
4. Development of management procedures (MPs) with harvest control rules (HCRs)
5. Simulation trials
6. Comparison of performance for various procedures
7. Advice of MPs which meet management objectives and select an MP

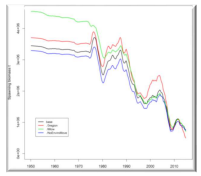
## Operating Models (OMs)

Usually based on existing stock-assessment with

- Best-available information
- Plausible range of biological ecological parameters



- As virtual reality
- Uncertainty with respect to
  - data
  - parameters
  - models
  - estimation
  - stochastic process in population
  - implementation



## Management Procedures (MPs)

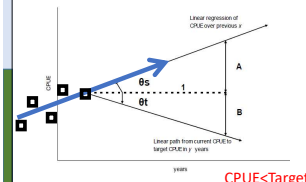
MPs including HCRs
- Predetermined rules to set catch limit
- Data collection and assessment

Note: Any MPs do not know the reality of OMs !!
- Kinds of blind tests
- If MPs know OMs, just like "judge" and "prosecutor" is a same person

## Currently two types of MPs

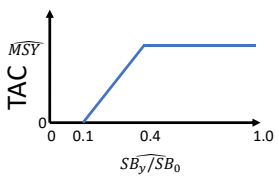
1) **Empirical (model-free, CPUE-based)**
2) **Model-based (with a simple stock assessment)**

**1) Empirical MP:**
Aims to keep the stock near a target CPUE

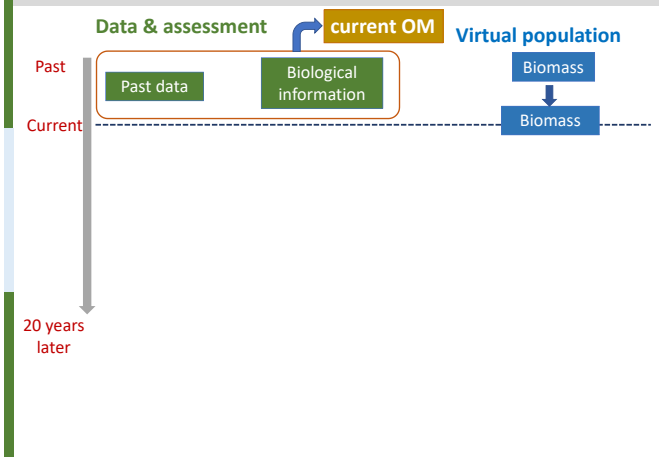



CPUE<Target
TAC decrease

**2) Model-based MP:**
- Fits a Pella-Tomlinson surplus production model,
- Set the TAC using a 40:10-type HCR



## Update of MPs

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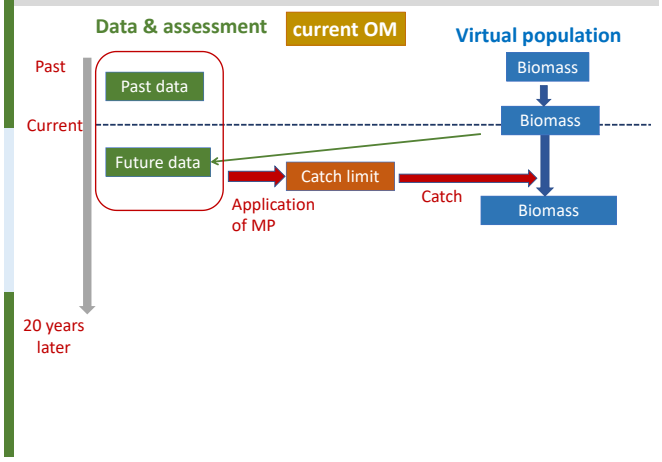


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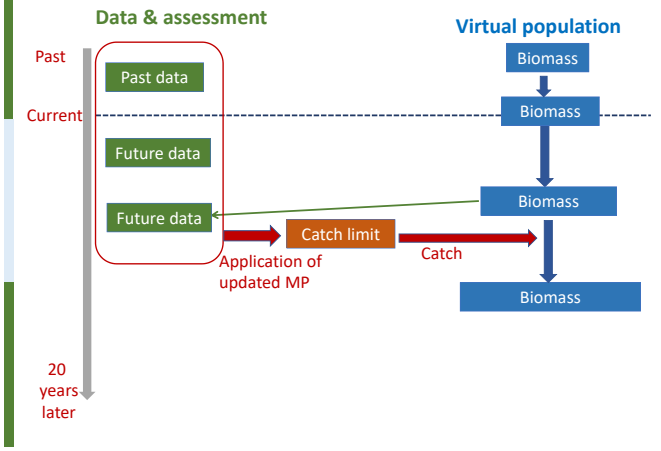


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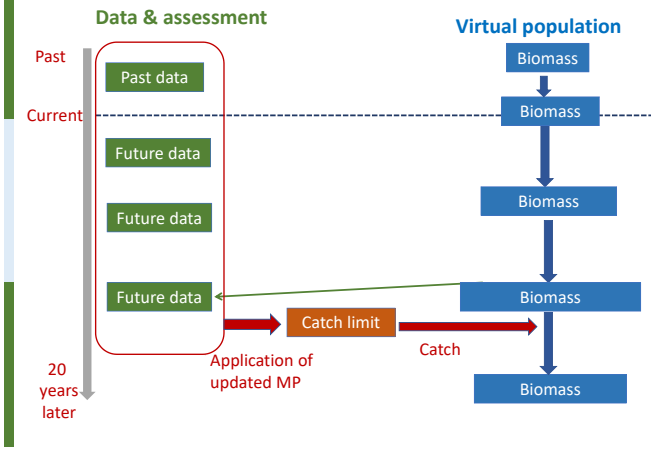



## Performance statistics

1) Status and safety of population
   - Maximize the population size
   - Maximize the probability of remaining above low stock status (i.e. minimize risk)

2) Catch and stability
   - Maximize catches across regions and gears
   - Maximize catch rates to enhance fishery profitability
   - Maximize stability in catches to reduce commercial uncertainty

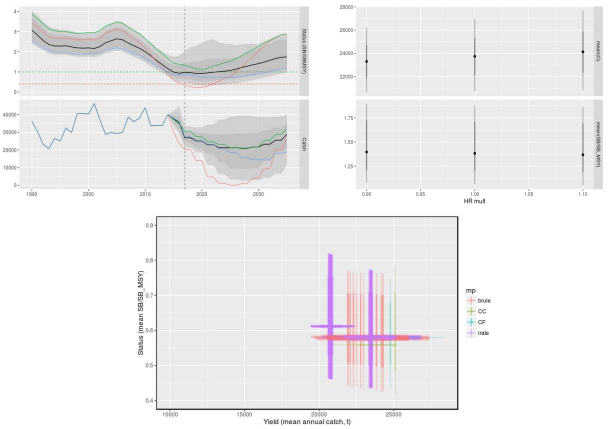
## Performance statistics in detail: "Population"

| | | |
|---|---|---|
| **Status : maximize stock status** | | |
| 1. Mean spawner biomass relative to pristine | $SB/SB_0$ | Arithmetic mean over years |
| 2. Minimum spawner biomass relative to pristine | $SB/SB_0$ | Minimum over years |
| 3. Mean spawner biomass relative to $SB_{MSY}$ | $SB/SB_{MSY}$ | Arithmetic mean over years |
| 4. Mean fishing mortality relative to target | $F/F_{tar}$ | Arithmetic mean over years |
| 5. Mean fishing mortality relative to Fmsy | $F/F_{MSY}$ | Arithmetic mean over years |
| 6. Probability of being in Kobe green quadrant | SB,F | Proportion of years that $SB \geq SB_{tar}$ and $F \leq F_{tar}$ |
| 7. Probability of being in Kobe red quadrant | SB,F | Proportion of years that $SB < SB_{tar}$ and $F > F_{tar}$ |
| **Safety : maximize the probability of remaining above low stock status (i.e. minimize risk)** | | |
| 8. Probability of spawner biomass being above 20% of $SB_0$ | SB | Proportion of years that $SB > 0.2B_0$ |
| 9. Probability of spawner biomass being above $B_{Lim} = 0.4SB_{MSY}$ | SB | Proportion of years that $SB > 0.4SB_{MSY}$ |

## Performance statistics in detail: "Catch"

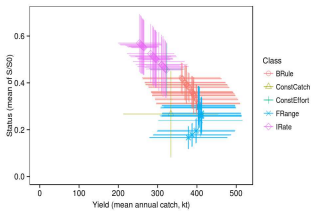
| | | |
|---|---|---|
| **Yield : maximize catches across regions and gears** | | |
| **10. Mean catch** | C | Arithmetic mean over years |
| **11. Mean catch by region and/or gear** | C | Arithmetic mean over years |
| **12. Mean catch relative to MSY** | C/MSY | Arithmetic mean over years |
| **Abundance: maximize catch rates to enhance fishery profitability** | | |
| **13. Mean catch rates by region and gear (for fisheries with meaningful catch-effort relationship)** | I | Arithmetic mean over years |
| **Stability: maximize stability in catches to reduce commercial uncertainty** | | |
| **14. Mean absolute proportional change in catch** | C | Arithmetic mean over years of abs(1-$C_t/C_{t-1}$) |
| **15. Variance in catch** | C | Variance over years |
| **16. Probability of shutdown** | C | Proportion of years that C< 0.1MSY |

## Update of MPs

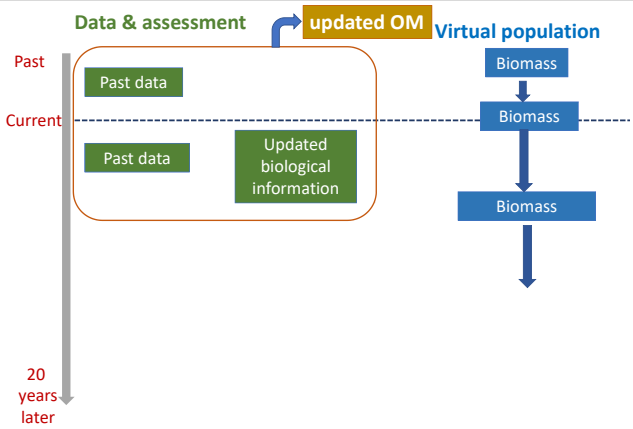


## Trade-off

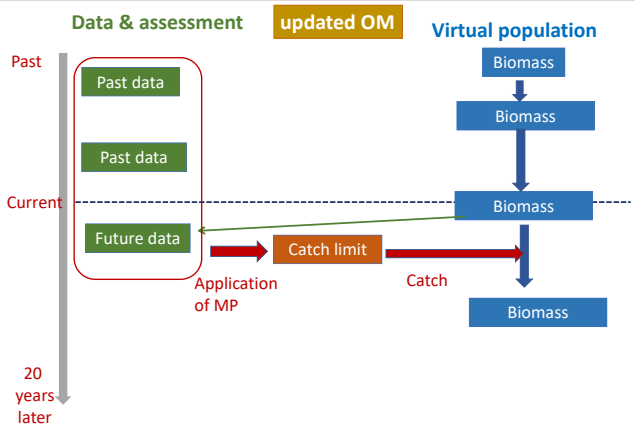
- ✓ Stock status $SB/SB_{MSY}$ (or SB/SB0 for skipjack) vs. Yield
- ● Stock status Pr(Green Kobe) vs. Yield
- ● Stock status Pr(SB > $B_{Lim}$) vs. Yield
- ● Stability in Catch vs. Yield



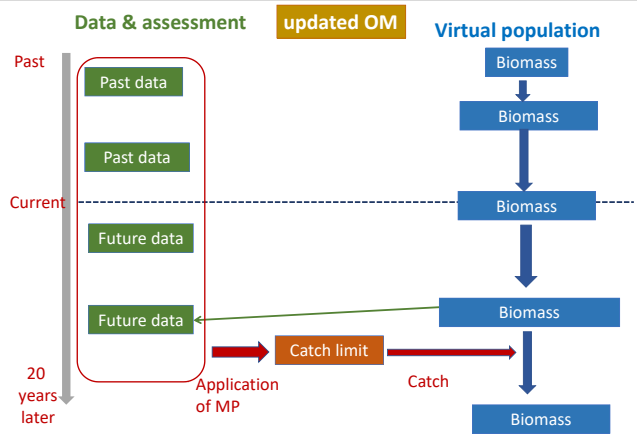

## Update of MSE (OMs and MPs)




## Review of MSE (update of OMs and MPs)

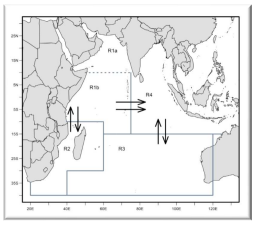


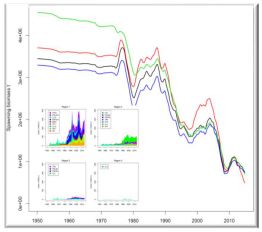

## Review of MSE (update of OMs and MPs)



## Develop an OM to simulate yellowfin and bigeye tuna population and fishery dynamics

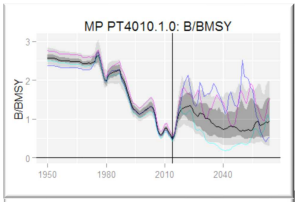
- R-based MSE control and projection software is functional
- Preliminary yellowfin and bigeye operating models have been conditioned in conjunction with recent *Stock Synthesis* assessments
- Further improvements in computational efficiency are under development – estimated completion June 2016

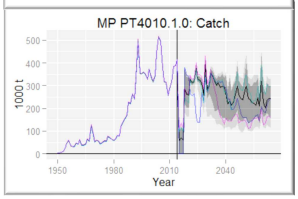


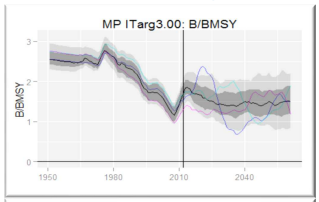
## Performance over time

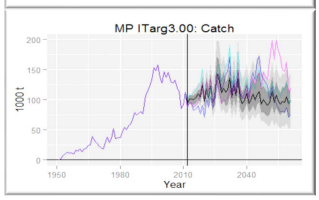
**Yellowfin**
**MP: PT4010**



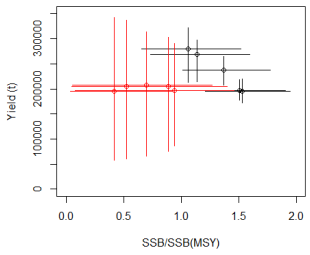

**Bigeye**
**MP: CPUE Target**



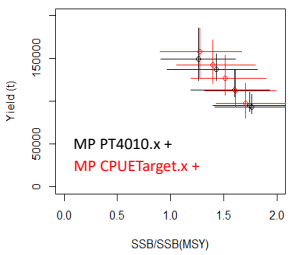




## Relation between performance statistics: trade-off plots

**Yellowfin**




**Bigeye**

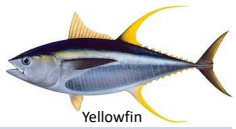



Averages over 20 year projection period

NB. These are demonstration results, not to be used for decision-making

## Proposed Yellowfin Management Procedure Tuning Targets from IOTC Resolutions

| | Tuning Objective | Rationale |
|---|---|---|
| 1) | Pr(SB(2024)>SBtarg) = 0.5<br><br>50% probability that spawning biomass rebuilds to the interim target level by 2024 | CMM 16/01 preamble: "*...recover the stocks to levels above the interim target reference points with 50% probability by 2024*" |
| 2) | Pr(SB>SBtarg) = 0.5<br><br>50% probability that the average spawning biomass equals or exceeds the interim biomass target for years 2019-2039 | CMM 15/10 (annex 1): "*...achieve target reference points on average*" |

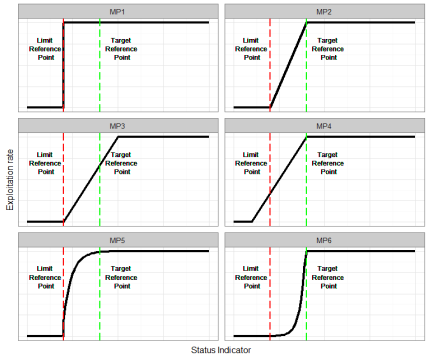

Yellowfin

## Standard presentations in IOTC

**Hypothetical example**

- 6 MPs (HCR component only)
- Focus on the type of information conveyed, not specific results
- Figures and tables are suggestions only – feedback encouraged!
- Remember this is a hypothetical example – no real data!

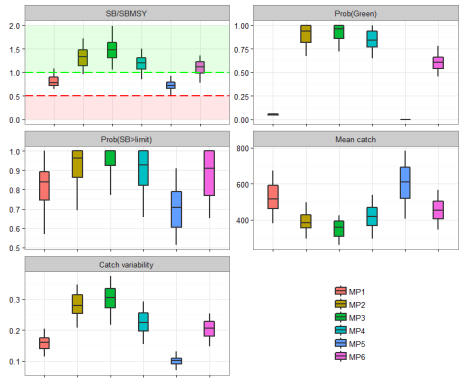
## 1. Illustrate and define candidate MPs or HCRs



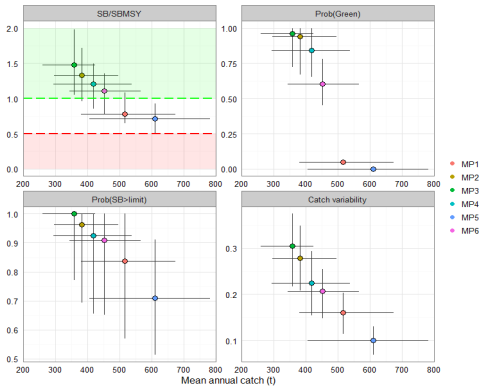
## 1. Illustrate and define candidate MPs or HCRs

| Management Procedure | Brief description |
|---|---|
| MP1 | Full recommended exploitation rate when current biomass is equal to or greater than 20% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass. |
| MP2 | Full recommended exploitation rate when current biomass is equal to or greater than 40% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass; Recommended exploitation rate declines linearly between 40% and 20% of unfished biomass. |
| MP3 | Full recommended exploitation rate when current biomass is equal to or greater than 50% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass; Recommended exploitation rate declines linearly between 50% and 20% of unfished biomass. |
| MP4 | Full recommended exploitation rate when current biomass is equal to or greater than 40% of unfished biomass; No exploitation when current biomass less than 10% of unfished biomass; Recommended exploitation rate declines linearly between 40% and 10% of unfished biomass. |
| MP5 | Full recommended exploitation rate when current biomass is equal to or greater than 40% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass; Recommended exploitation rate increases exponentially between 20% and 40% of unfished biomass. |
| MP6 | Full recommended exploitation rate when current biomass is equal to or greater than 40% of unfished biomass; No exploitation when current biomass less than 20% of unfished biomass; Recommended exploitation rate declines exponentially between 40% and 20% of unfished biomass. |

## 2. Performance of MPs (boxplots)



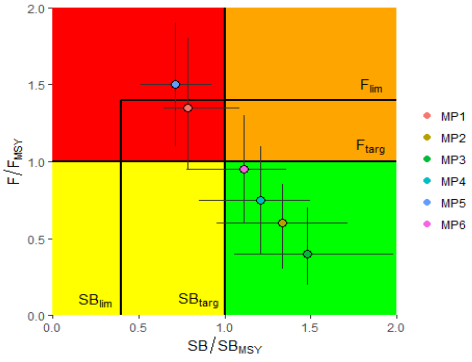

## 2. Performance of MPs (trade-off plots)



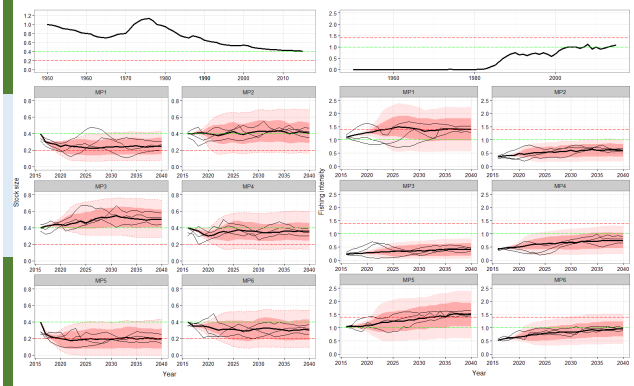

## 2. Performance of MPs (summary table)

| Management Procedure | Performance Measure | | | | |
|---|---|---|---|---|---|
| | $SB/SB_{MSY}$ | Prob(Green) | Prob(SB>limit) | Mean Catch | Catch variability |
| MP1 | 0.78 | 0.05 | 0.84 | 516 | 0.16 |
| MP2 | 1.33 | 0.94 | 0.96 | 383 | 0.28 |
| MP3 | 1.48 | 0.96 | 1 | 358 | 0.3 |
| MP4 | 1.21 | 0.84 | 0.93 | 419 | 0.22 |
| MP5 | 0.72 | 0 | 0.71 | 611 | 0.1 |
| MP6 | 1.11 | 0.61 | 0.91 | 452 | 0.21 |

## 2. Performance of MPs (KOBE plot)




## 2. Performance of MPs (time series plots)



## 3. Summary report (numeric comparison)

| **Status : maximize stock status** | | 1 year | | | | | | 5 years | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 |
| 1. Mean spawner biomass relative to pristine | *SB/SB0* | 0.5 | 0.8 | 0.9 | 0.7 | 0.4 | 0.6 | 0.5 | 0.8 | 1.0 | 0.7 | 0.4 | 0.6 |
| 2. Minimum spawner biomass relative to pristine | *SB/SB0* | 0.3 | 0.6 | 0.6 | 0.5 | 0.2 | 0.4 | 0.3 | 0.5 | 0.6 | 0.5 | 0.2 | 0.4 |
| 3. Mean spawner biomass relative to $SB_{MSY}$ | *SB/SBMSY* | 0.8 | 1.3 | 1.4 | 1.2 | 0.7 | 1.1 | 0.9 | 1.2 | 1.3 | 1.1 | 0.7 | 1.2 |
| 4. Mean fishing mortality relative to target | *F/Ftar* | 1.4 | 0.6 | 0.4 | 0.8 | 1.5 | 0.9 | 1.4 | 0.6 | 0.4 | 0.8 | 1.5 | 0.9 |
| 5. Mean fishing mortality relative to *Fmsy* | *F/FMSY* | 1.4 | 0.6 | 0.4 | 0.8 | 1.5 | 0.9 | 1.5 | 0.5 | 0.4 | 0.8 | 1.6 | 0.9 |
| 6. Probability of being in Kobe green quadrant | *SB,F* | 0.5 | 0.9 | 1 | 0.8 | 0.3 | 0.7 | 0.5 | 0.9 | 0.9 | 0.8 | 0.3 | 0.7 |
| 7. Probability of being in Kobe red quadrant | *SB,F* | 0.3 | 0.1 | 0 | 0.1 | 0.5 | 0.2 | 0.3 | 0.1 | 0.0 | 0.1 | 0.5 | 0.2 |
| ***Safety : maximize the probability of remaining above low stock status (i.e. minimize risk)*** | | | | | | | | | | | | | |
| 8. Probability of spawner biomass being above 20% of *SB0* | *SB* | 0.8 | 0.9 | 0.9 | 0.8 | 0.7 | 0.8 | 0.8 | 0.8 | 0.9 | 0.8 | 0.7 | 0.8 |
| 9. Probability of spawner biomass being above *B*Lim | *SB* | 0.8 | 1.0 | 1.0 | 0.9 | 0.7 | 0.9 | 0.8 | 1.0 | 1.0 | 0.9 | 0.7 | 0.8 |
| ***Yield : maximize catches across regions and gears*** | | | | | | | | | | | | | |
| 10. Mean catch (1'000 t) | *C* | 520 | 390 | 350 | 430 | 600 | 460 | 551 | 417 | 378 | 434 | 600 | 460 |
| 11. Mean catch by region and/or gear (1'000 t) | *C* | 250 | 200 | 180 | 210 | 310 | 220 | 248 | 194 | 176 | 229 | 335 | 218 |
| 12. Mean catch relative to MSY | *C/MSY* | 1.1 | 0.7 | 0.6 | 0.8 | 1.2 | 0.9 | 1.2 | 0.6 | 0.6 | 0.8 | 1.3 | 1.0 |
| ***Abundance: maximize catch rates to enhance fishery profitability*** | | | | | | | | | | | | | |
| 13. Mean catch rates (by region and gear) (for fisheries with meaningful catch-effort relationship) | *I* | 3.2 | 3.8 | 3.9 | 2.7 | 2.5 | 2.6 | 3.0 | 3.8 | 4.0 | 2.6 | 2.3 | 2.8 |
| ***Stability: maximize stability in catches to reduce commercial uncertainty*** | | | | | | | | | | | | | |
| 14. Mean absolute proportional change in catch | *C* | 0.2 | 0.3 | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 | 0.1 | 0.2 |
| 15. % Catch co-efficient of variation | *C* | 20 | 25 | 24 | 18 | 12 | 21 | 19.4 | 27.3 | 26.2 | 17.6 | 11.5 | 21.0 |
| 16. Probability of shutdown | *C* | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

## 3. Summary report (scientific advice)

| **Status : maximize stock status** | | 10 years | | | | | | 20 years | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 |
| 1. Mean spawner biomass relative to pristine | *SB/SB0* | 0.5 | 0.8 | 0.9 | 0.7 | 0.4 | 0.6 | 0.5 | 0.8 | 1.0 | 0.7 | 0.4 | 0.6 |
| 2. Minimum spawner biomass relative to pristine | *SB/SB0* | 0.3 | 0.6 | 0.6 | 0.5 | 0.2 | 0.4 | 0.3 | 0.5 | 0.6 | 0.5 | 0.2 | 0.4 |
| 3. Mean spawner biomass relative to $SB_{MSY}$ | *SB/SBMSY* | 0.8 | 1.3 | 1.4 | 1.2 | 0.7 | 1.1 | 0.9 | 1.2 | 1.3 | 1.1 | 0.7 | 1.2 |
| 4. Mean fishing mortality relative to target | *F/Ftar* | 1.4 | 0.6 | 0.4 | 0.8 | 1.5 | 0.9 | 1.4 | 0.6 | 0.4 | 0.8 | 1.5 | 0.9 |
| 5. Mean fishing mortality relative to *Fmsy* | *F/FMSY* | 1.4 | 0.6 | 0.4 | 0.8 | 1.5 | 0.9 | 1.5 | 0.5 | 0.4 | 0.8 | 1.6 | 0.9 |
| 6. Probability of being in Kobe green quadrant | *SB,F* | 0.5 | 0.9 | 1 | 0.8 | 0.3 | 0.7 | 0.5 | 0.9 | 0.9 | 0.8 | 0.3 | 0.7 |
| 7. Probability of being in Kobe red quadrant | *SB,F* | 0.3 | 0.1 | 0 | 0.1 | 0.5 | 0.2 | 0.3 | 0.1 | 0.0 | 0.1 | 0.5 | 0.2 |
| ***Safety : maximize the probability of remaining above low stock status (i.e. minimize risk)*** | | | | | | | | | | | | | |
| 8. Probability of spawner biomass being above 20% of *SB0* | *SB* | 0.8 | 0.9 | 0.9 | 0.8 | 0.7 | 0.8 | 0.8 | 0.8 | 0.9 | 0.8 | 0.7 | 0.8 |
| 9. Probability of spawner biomass being above *B*Lim | *SB* | 0.8 | 1.0 | 1.0 | 0.9 | 0.7 | 0.9 | 0.8 | 1.0 | 1.0 | 0.9 | 0.7 | 0.8 |
| ***Yield : maximize catches across regions and gears*** | | | | | | | | | | | | | |
| 10. Mean catch (1'000 t) | *C* | 520 | 390 | 350 | 430 | 600 | 460 | 551 | 417 | 378 | 434 | 600 | 460 |
| 11. Mean catch by region and/or gear (1'000 t) | *C* | 250 | 200 | 180 | 210 | 310 | 220 | 248 | 194 | 176 | 229 | 335 | 218 |
| 12. Mean catch relative to MSY | *C/MSY* | 1.1 | 0.7 | 0.6 | 0.8 | 1.2 | 0.9 | 1.2 | 0.6 | 0.6 | 0.8 | 1.3 | 1.0 |
| ***Abundance: maximize catch rates to enhance fishery profitability*** | | | | | | | | | | | | | |
| 13. Mean catch rates (by region and gear) (for fisheries with meaningful catch-effort relationship) | *I* | 3.2 | 3.8 | 3.9 | 2.7 | 2.5 | 2.6 | 3.0 | 3.8 | 4.0 | 2.6 | 2.3 | 2.8 |
| ***Stability: maximize stability in catches to reduce commercial uncertainty*** | | | | | | | | | | | | | |
| 14. Mean absolute proportional change in catch | *C* | 0.2 | 0.3 | 0.3 | 0.2 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 | 0.1 | 0.2 |
| 15. % Catch co-efficient of variation | *C* | 20 | 25 | 24 | 18 | 12 | 21 | 19.4 | 27.3 | 26.2 | 17.6 | 11.5 | 21.0 |
| 16. Probability of shutdown | *C* | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |

## 3. Summary report (scientific advice)

- **MP1** achieved the second highest catches, and second lowest level of catch variability. There was a 5% chance that MP1 would be at or above the biomass target reference point and 2% chance it would be at or below the fishing mortality target reference point. There is a 25% risk that MP1 will cause the spawning biomass to fall below the limit reference point and a 50% risk that MP1 will cause the fishing mortality to exceed the limit reference point over the next 20 years.
- **MP2** performed …
- **MP3** performed …
- **MP4** performed …
- **MP5** performed …
- **MP6** performed …