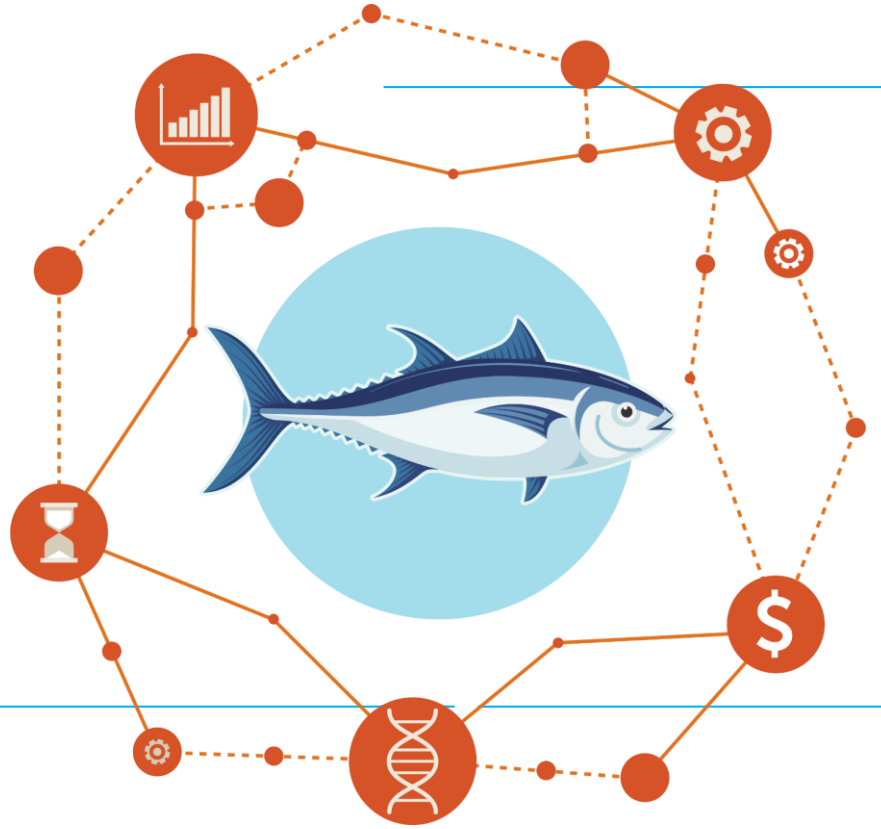
# An SCRS Update on BFT Management Strategy Evaluation (MSE)



October 2021

*References*


1. BFT MSE summary 4-page
2. BFT MSE summary 1-page

# General Information for SCRS/BFT WG – MSE Ambassador Meetings

Primary Objective: To provide all stakeholders with a basic understanding of the MSE approach, performance indicators and the tradeoffs associated with different CMP's.

Our approach is:

– *To undertake a series of standard virtual presentations in all three official ICCAT languages with a focus MSE and associated issues.*

– *To encourage participants to openly ask questions in their own language about how MSE works and/or regarding aspects of MSE they don't understand.*

– *To promote open discussion/questions on the floor during the meeting for all to hear rather than to have multiple discussions in the "Chat".*

Questions or discussions on Policy or the 2021 SCRS advisory report management recommendations are discouraged and will not be entertained during these meetings

# Presentation Overview:

- What is MSE and Management Procedures?
- BFT MSE specifics
  - Operating models
  - Indices
  - Management Procedures
- Preliminary results
- Next steps

SCRS on track to present 2-3 final CMPs to the Commission in 2022 for providing TAC advice starting in 2023, after feedback from Panel 2.

# *What is Management Strategy Evaluation*

- ***Management Strategy Evaluation*** *is a means to develop a robust, consensus-driven and realistic* ***Management Procedure.*** *It is an iterative process that involves substantial dialogue between Scientists, Managers, and Stakeholders.*

- **Management procedure (MP)**: *A pre-agreed framework for setting catch limits, designed to achieve specific* ***management objectives****.*

- **Management objectives (MO):** *Formally adopted goals for the fishery.*

# A Brief Overview of Management Procedures

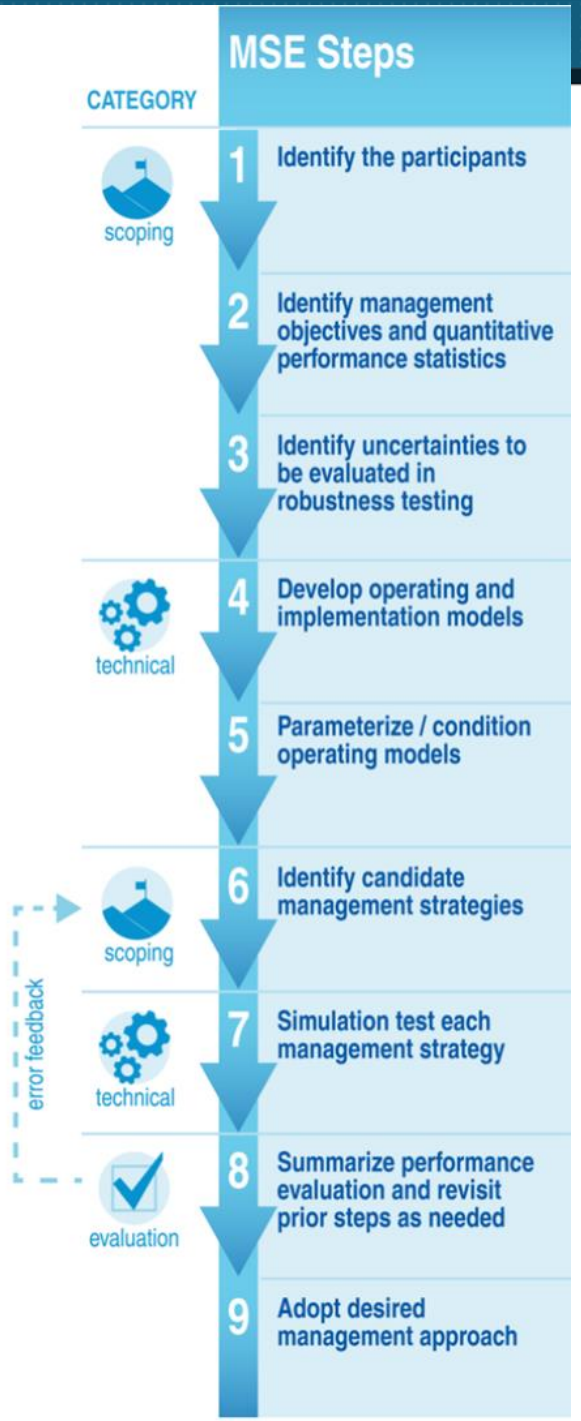
- A **pre-agreed framework** for making management decisions
- Evaluated and selected using **MSE**
- Three main elements

**Monitoring** data with collection plan

**Analysis method** (ex: evaluation of level and trend in indices)

**Harvest control rule** (HCR)

# Diagram of MSE Process

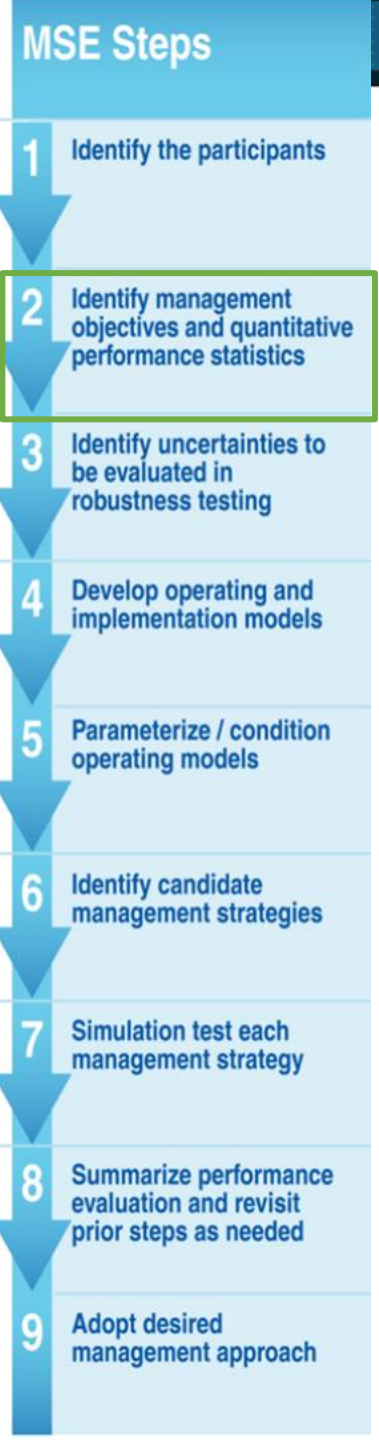



**Management objectives**

**Operating models**

**Management procedures**

Goethel et al. 2019 Closing the Feedback Loop: On Stakeholder Participation in Management Strategy Evaluation. CJFAS




# *Management objectives*

- ***Conceptual Management Objectives***: Desired goals for fishery
- ***Operational Management Objectives***: Specific, codified and measurable objectives, with timelines and minimum required probabilities

**Conceptual**: Want stable TAC

**Operational**: TAC varies by less than 20% in each year

# Management Objectives for this MSE

- Per Resolution 18-03

- The stock should have a greater than [__]% probability of occurring in the green quadrant of the Kobe matrix
- There should be a less than [__]% probability of the stock falling below $B_{LIM}$ (to be defined)
- Maximize overall catch levels
- Any increase or decrease in TAC between management periods should be less than [__]%

# Performance Statistics for this MSE

- The stock should have a greater than [__]% probability of occurring in the green quadrant of the Kobe matrix
- There should be a less than [__]% probability of the stock falling below $B_{LIM}$ (to be defined)
- Maximize overall catch levels
- Any increase or decrease in TAC between management periods should be less than [__]%

- **AvgBr** – Average Br [i.e., biomass ratio, or spawning stock biomass (SSB) relative to dynamic $SSB_{MSY}$] over projection years 11-30
- **Br30** – Br after 30 years
- **OFT** – Overfished Trend, SSB trend if Br30<1.
- [F statistic – once finalized]

# Performance Statistics for this MSE

- The stock should have a greater than [__]% probability of occurring in the green quadrant of the Kobe matrix
- There should be a less than [__]% probability of the stock falling below $B_{LIM}$ (to be defined)
- Maximize overall catch levels
- Any increase or decrease in TAC between management periods should be less than [__]%

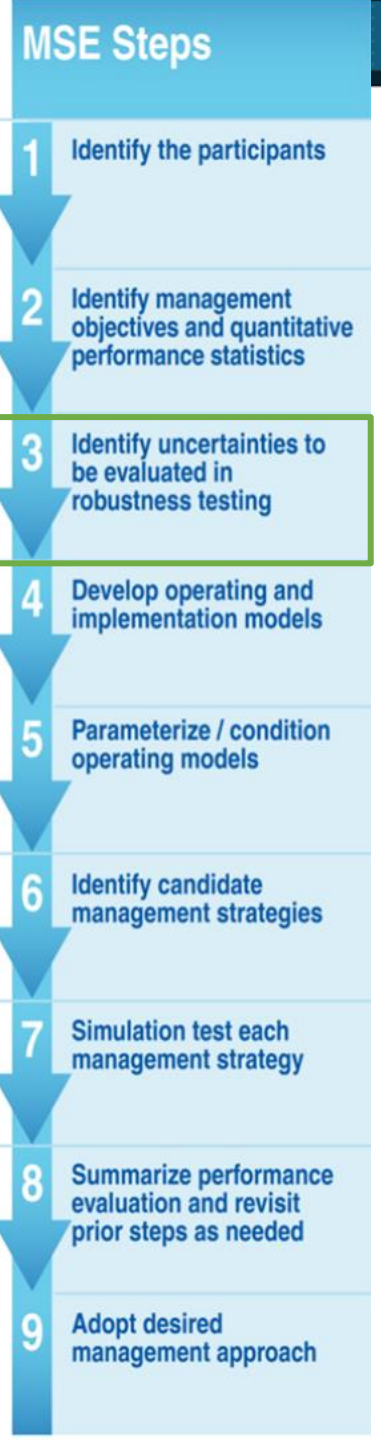
- **LD** – Lowest depletion (i.e., SSB relative to dynamic $SSB_0$[2]) over 30-year projection period

# Performance Statistics for this MSE

- The stock should have a greater than [__]% probability of occurring in the green quadrant of the Kobe matrix
- There should be a less than [__]% probability of the stock falling below $B_{LIM}$ (to be defined)
- Maximize overall catch levels
  - **AvC10** – Mean catches (t) over first 10 years
  - **AvC30** – Mean catches (t) over 30 years
- Any increase or decrease in TAC between management periods should be less than [__]%

# Performance Statistics for this MSE

- The stock should have a greater than [__]% probability of occurring in the green quadrant of the Kobe matrix
- There should be a less than [__]% probability of the stock falling below $B_{LIM}$ (to be defined)
- Maximize overall catch levels
- Any increase or decrease in TAC between management periods should be less than [__]%
  - **AAVC** – Average annual variation in catches (%)




# Key Concepts: Operating Models

- **Operating model (OM):** A model representing a plausible scenario for stock and fishery dynamics that is used to simulation test the management performance of CMPs.

# Key Concepts: Identifying Uncertainties

- Multiple OMs will usually be considered to reflect the uncertainties about the dynamics of the resource and fishery, thereby testing the robustness of management procedures.

MSE Steps

1. Identify the participants
2. Identify management objectives and quantitative performance statistics
3. Identify uncertainties to be evaluated in robustness testing
4. Develop operating and implementation models
5. Parameterize / condition operating models
6. Identify candidate management strategies
7. Simulation test each management strategy
8. Summarize performance evaluation and revisit prior steps as needed
9. Adopt desired management approach

# Key Concepts: Operating Models

**Reference set**: most plausible scenarios or hypotheses with greatest impact on outcomes, can be equally or differentially weighted

**Robustness set**: unlikely but still possible scenarios or hypotheses. What-if and worst-case scenarios.

**Reference set: screen all Management Procedures**

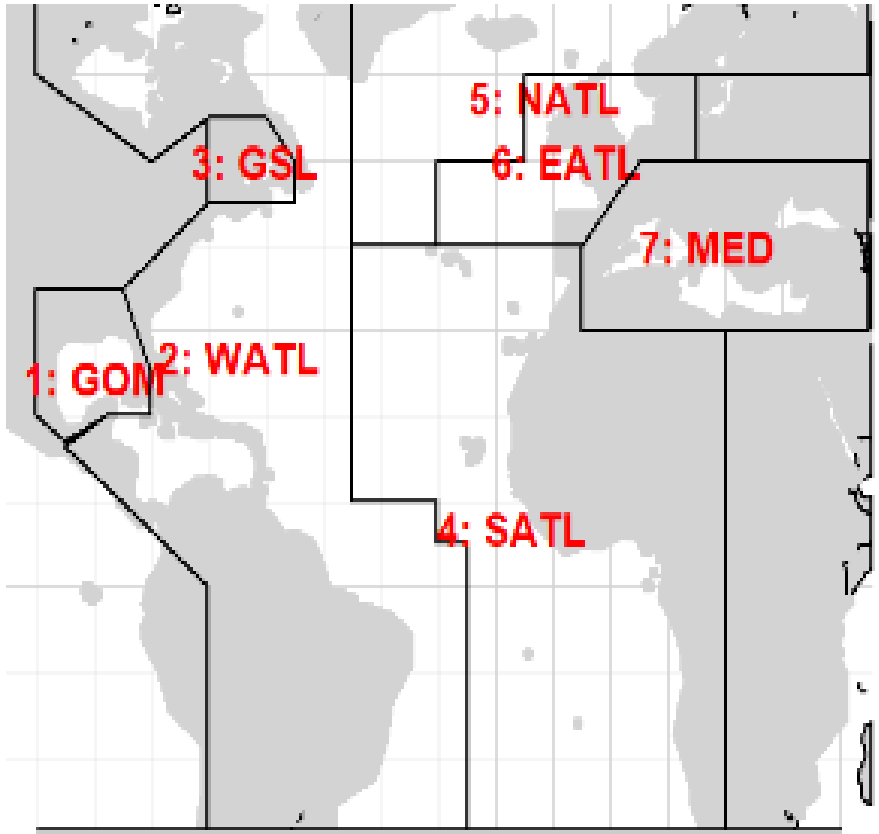
**Robustness set: screen top performing Management Procedures**

MSE Steps

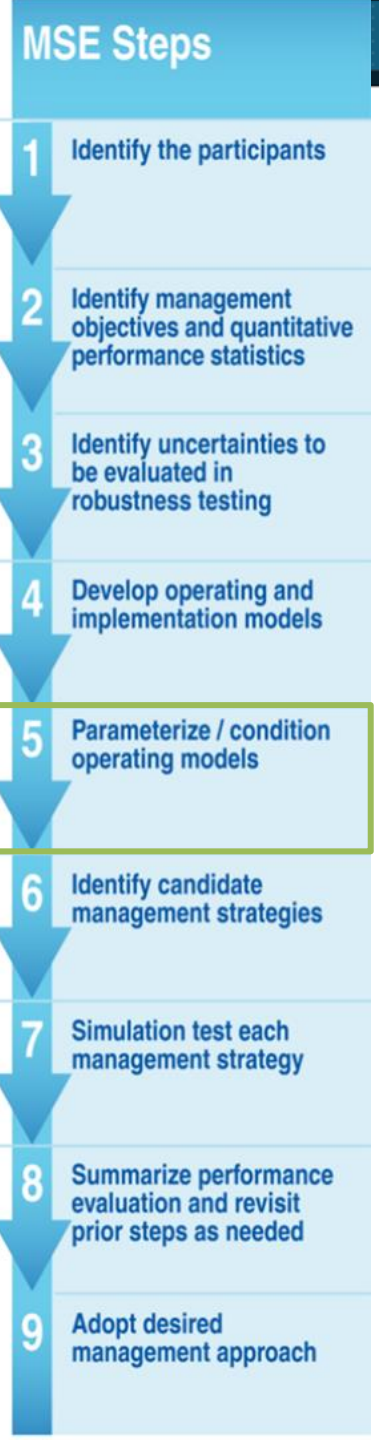
1. Identify the participants
2. Identify management objectives and quantitative performance statistics
3. Identify uncertainties to be evaluated in robustness testing
4. Develop operating and implementation models
5. Parameterize / condition operating models
6. Identify candidate management strategies
7. Simulation test each management strategy
8. Summarize performance evaluation and revisit prior steps as needed
9. Adopt desired management approach

# Operating Model structure

- Spatial definitions



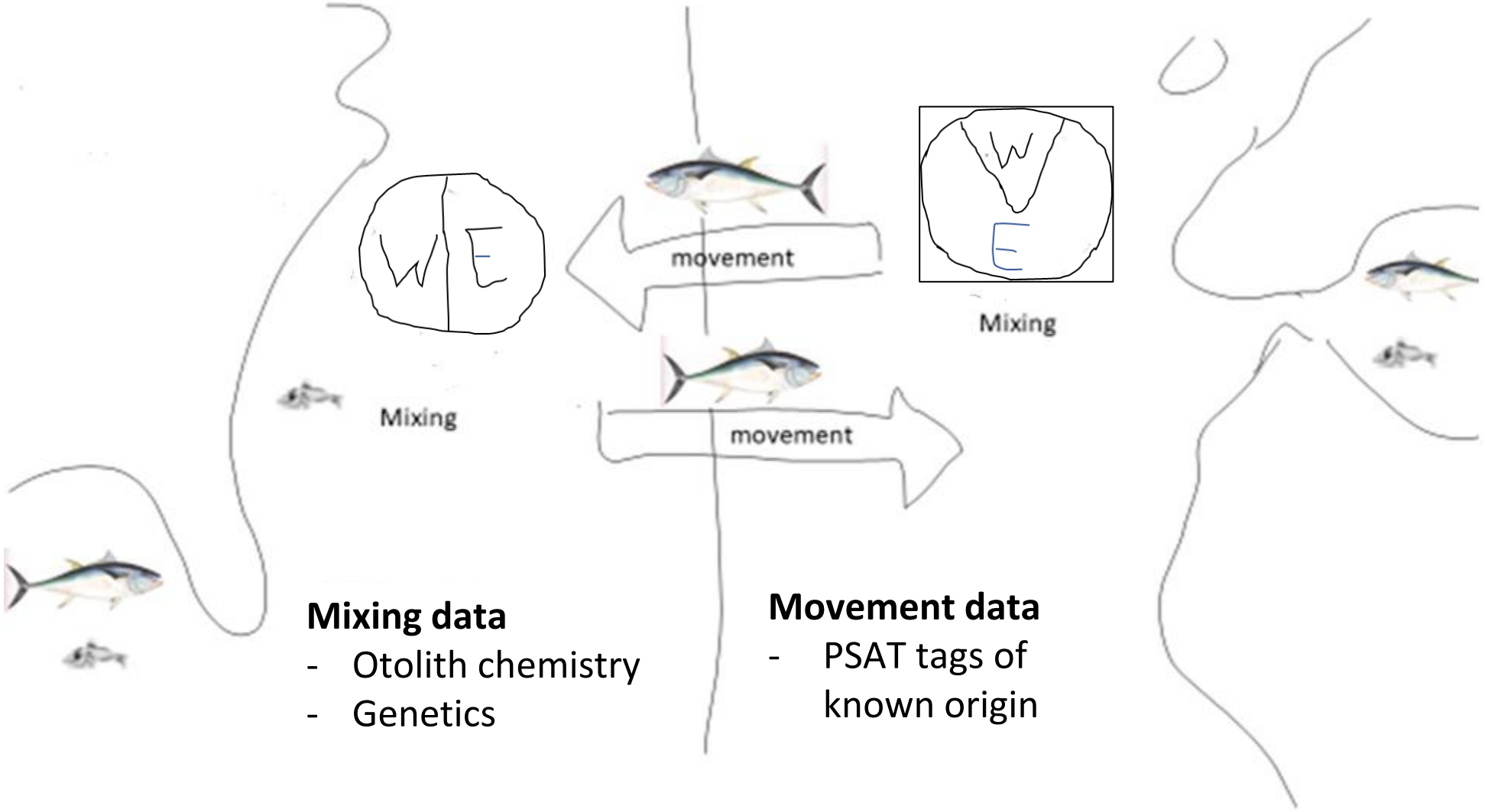

- Specifications
  - Time period (history) 1864-2019
  - 7-area model
  - 4 Quarters (Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec)
  - Spawning occurs for both stocks in quarter 2
    - Mediterranean for Eastern stock
    - Gulf of Mexico & Western Atlantic for Western stock
  - Age structured (3 age groups)
  - Multi-fleet (indices for fitting OM's)
    - 14 CPUE indices
    - 5 fishery independent indices




# **Conditioning:** Grounding operating models to data and assumptions

- i.e., ensure that they are consistent with historical data to be considered plausible
- OMs reflect full range of plausible past stock trajectories.
- fit to data, similar to fitting a stock assessment model, but with multiple assumptions about the population dynamics
- Key data for bluefin tuna: catch, indices, length composition, movement (electronic tags) and mixing (otolith chemistry and genetics)

# **Movement** (rate of fish moving) vs **mixing** (proportion in each area)




**Mixing data**
- Otolith chemistry
- Genetics

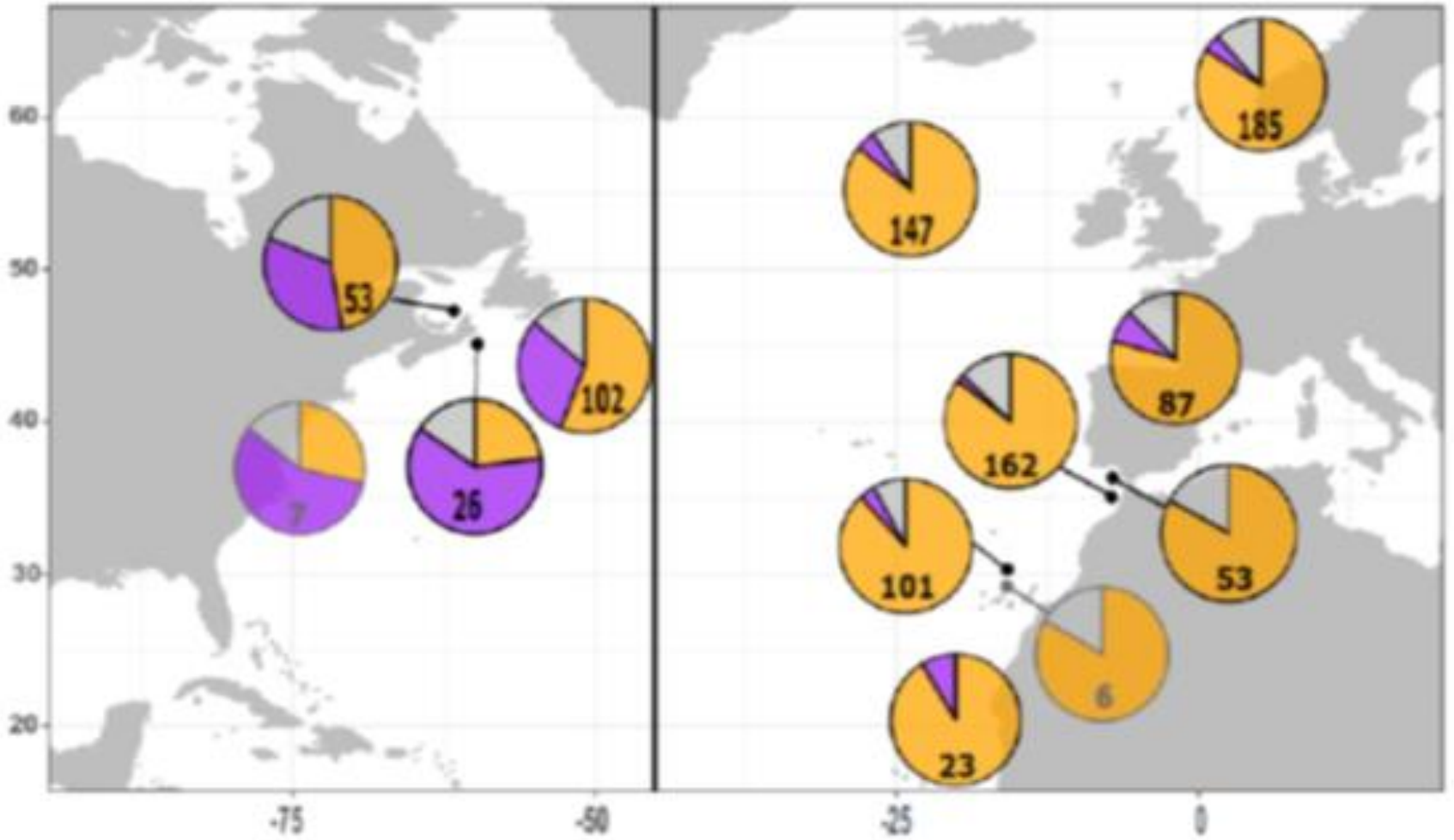
**Movement data**
- PSAT tags of known origin

# Genetic mixing data

Mediterranean (orange) or Gulf of Mexico (purple).

Black outline indicates mixing aggregates, grey outline indicates Slope Sea larvae and Canary island YOY.

Numbers are sample sizes.




Rodriguez-Ezpeleta et al (*2019*). Determining natal origin for improved management of Atlantic bluefin tuna. Frontiers in Ecology and the Environment

# Otolith microchemistry mixing data

**Table 1**. From Rooker et al. 2014. Predicted origin of medium and large bluefin tuna collected from different regions of the Atlantic Ocean and Mediterranean Sea based on a maximum likelihood estimator (MLE) and
maximum classification likelihood estimator (MCL). Estimates are given as percentages, and the mixed-stock analysis (HISEA program) was run under bootstrap mode with 500 runs to predict the error (±1 SD) around estimated percentages

| Region | N | MLE | | | MCL | | |
|---|---|---|---|---|---|---|---|
| | | % East | % West | % Error | % East | % West | % Error |
| **Central North Atlantic Ocean** | | | | | | | |
| 2010+2011 | 202 | 79.5 | 20.5 | 6.5 | 62.7 | 37.3 | 6.9 |
| 2010 | 108 | 63.9 | 36.1 | 9.6 | 47.7 | 52.3 | 9.0 |
| 2011 | 94 | 90.7 | 9.3 | 5.3 | 78.3 | 21.7 | 9.7 |
| West of 45° W | | | | | | | |
| 2010+2011 | 25 | 44.0 | 56.0 | 16.8 | 22.5 | 77.5 | 17.0 |
| East of 45° W | | | | | | | |
| 2010+2011 | 177 | 84.9 | 15.1 | 4.9 | 67.4 | 32.6 | 6.0 |
| 2010 | 106 | 60.9 | 39.1 | 8.5 | 46.1 | 53.9 | 8.4 |
| 2011 | 71 | 98.1 | 1.9 | 2.0 | 95.3 | 4.7 | 5.5 |
| **Northeast Atlantic Ocean** | | | | | | | |
| Morocco | 81 | 93.9 | 6.1 | 4.7 | 77.4 | 22.6 | 7.0 |
| Portugal | 93 | 100.0 | 0.0 | 0.0 | 97.5 | 2.5 | 3.7 |
| **Strait of Gibraltar** | | | | | | | |
| Spain | 97 | 100.0 | 0.0 | 0.0 | 99.6 | 0.4 | 1.4 |
| **Mediterranean Sea** | | | | | | | |
| Balearic Islands | 9 | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 |
| Sardinia | 20 | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 |
| Malta | 82 | 100.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 |
| Cyprus | 48 | 99.1 | 0.9 | 2.9 | 84.0 | 16.0 | 9.6 |

**Movement**. PSAT tracks from fish used in operating models. Left column fish less than 150 cm SFL, right column fish >= 150 cm SFL. Top row are fish that went definitively into the Gulf of Mexico spawning grounds. Middle row are fish that went definitively into the Mediterranean Sea

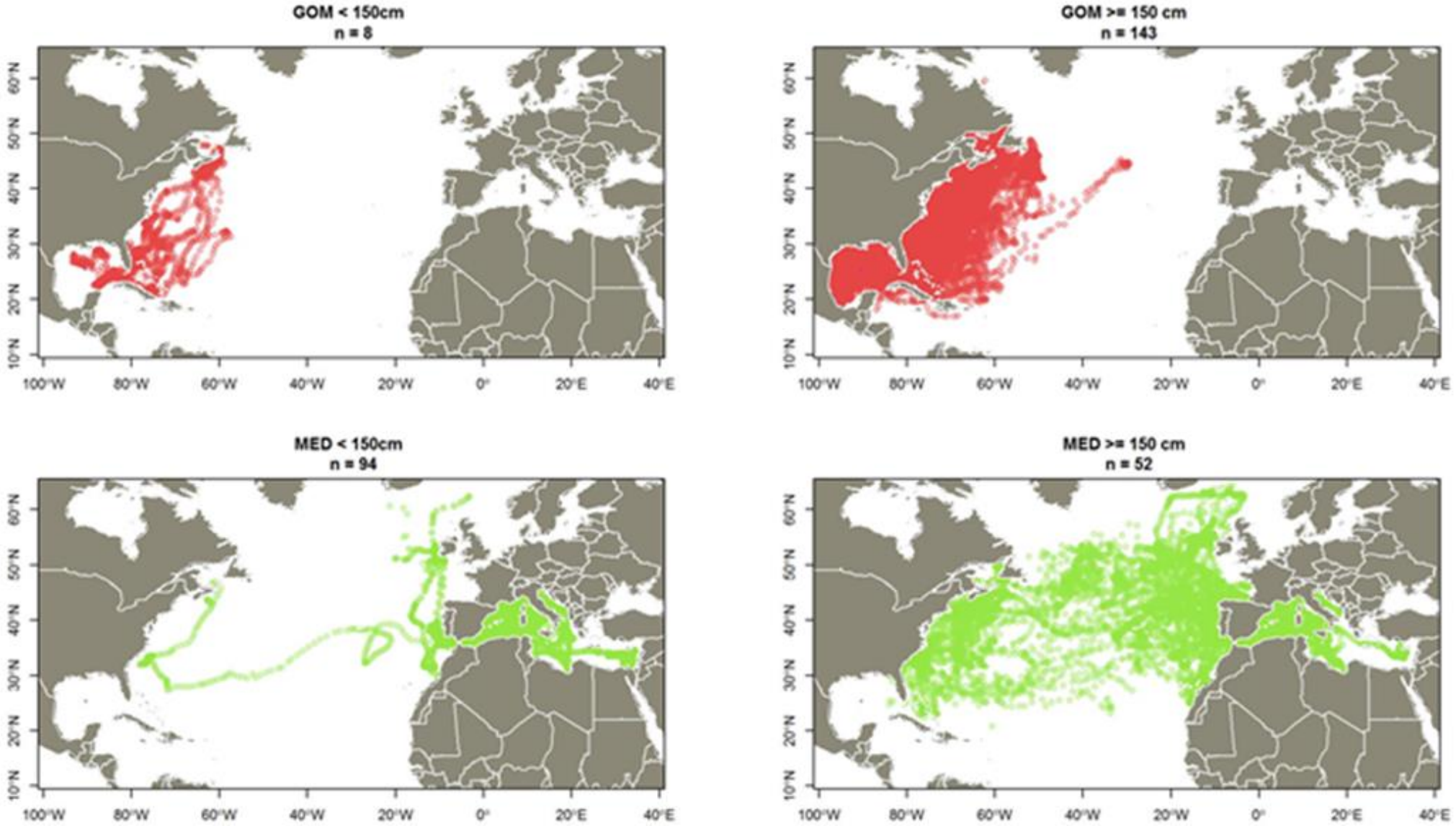
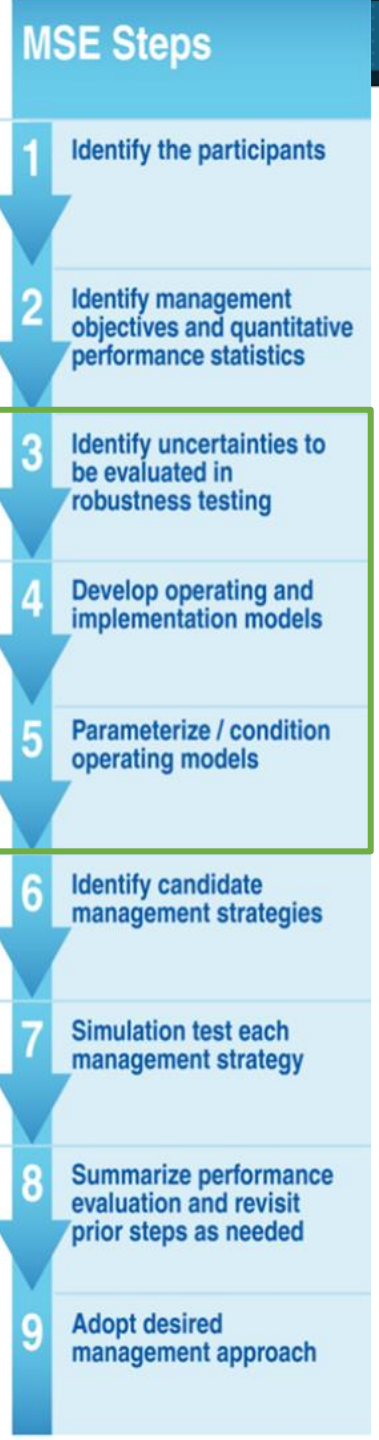


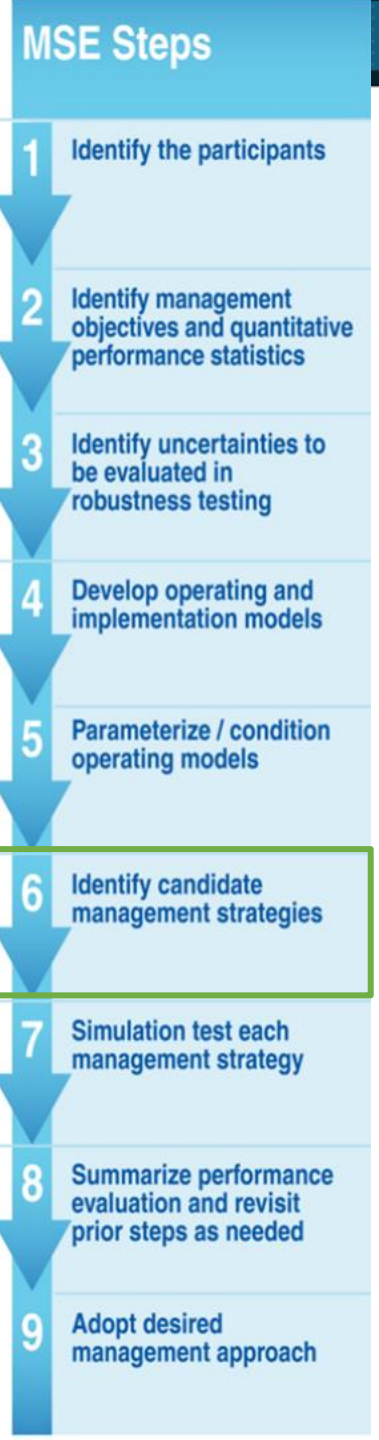

Figure courtesy of Ben Galuardi (NOAA-Fisheries)

# Reference Grid (% plausibility weight)

| Category of key uncertainties | Option 1 | Option 2 | Option 3 | Option 4 |
|---|---|---|---|---|
| Recruitment (age 1 fish) | western stock – "low" scenario (i.e., switch from high to low 70s); eastern stock – switch from low to high in 80s (40%) | western stock – "high" recruitment scenario; eastern stock – no regime shift, high recruitment (40%) | same as Level 1, with regime shift back to early period 10 years into the projections (20%) | |
| Spawning fraction/ Natural mortality (M) | Young spawning/ high M (50%) | Older spawning/ low M (with senescence) (50%) | | |
| Scale: abundance in each mgmt area | 15 kt W/200 kt E (30%) | 15 kt W/400 kt E (30%) | 50 kt W/200 kt E (15%) | 50 kt W/400 kt E (25%) |
| Length composition weighting | Low 0.05 (50%) | High 1 (50%) | | |




# Operating model questions




# Management procedures

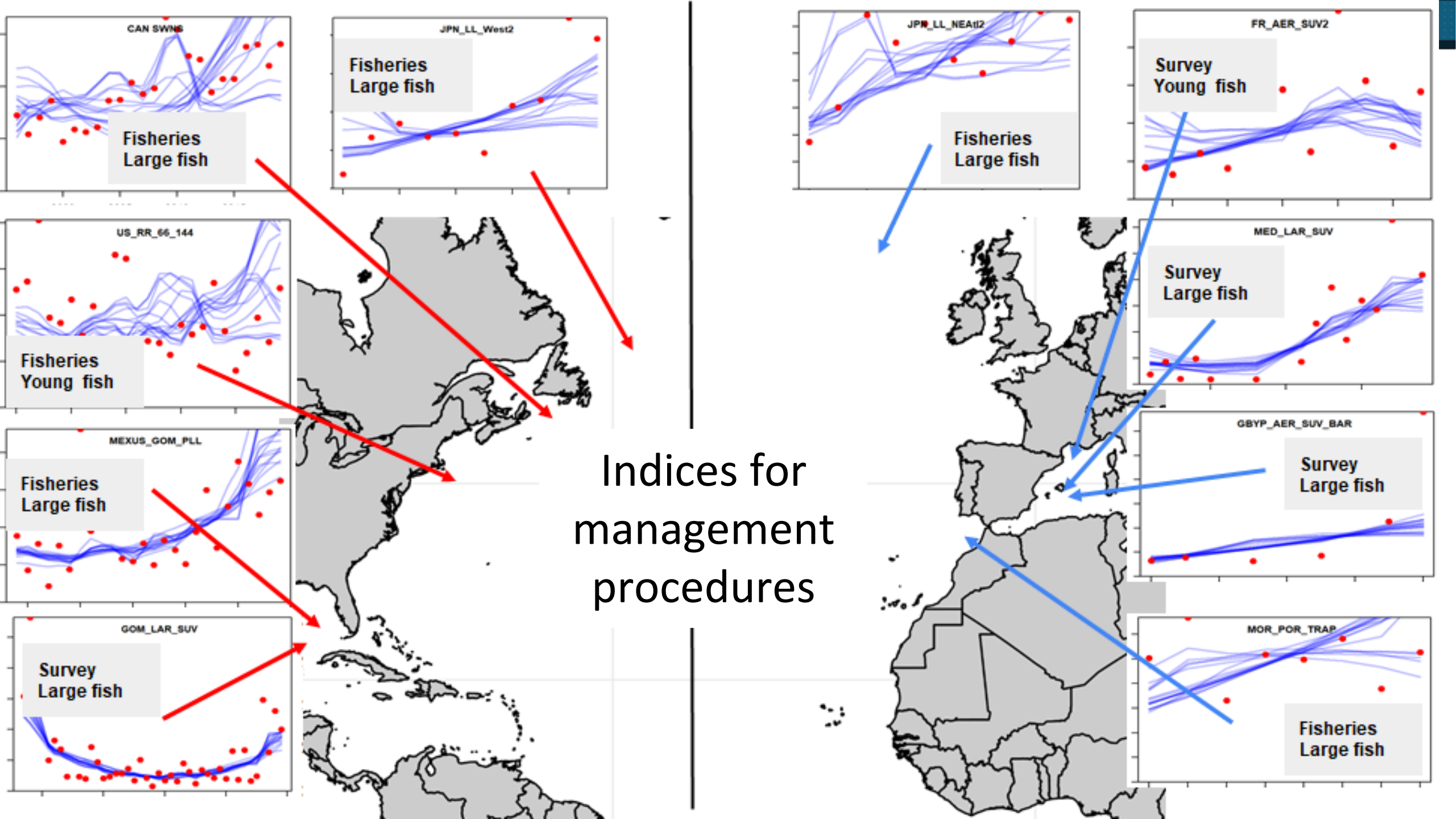
## Empirical management procedures

- Use empirical "proxies", such as indices
- Simple to explain and implement:

  index ↓ TAC ↓ and index ↑ TAC ↑

## Model based management procedures

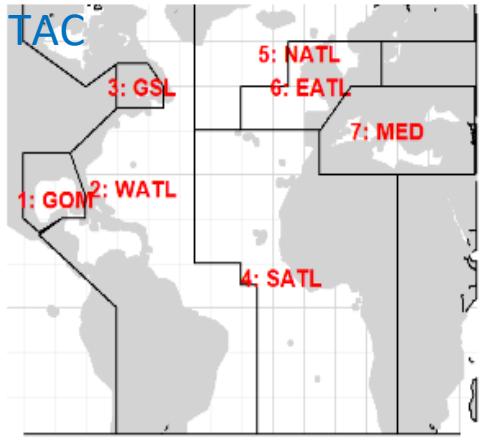
- Use quantities estimated from stock assessment model (e.g., $B_{MSY}$, $F_{MSY}$) to derive TAC advice.
- Similar to stock assessment advice framework


CAN SWNS
Fisheries
Large fish
JPN_LL_West2
Fisheries
Large fish
US_RR_66_144
Fisheries
Young fish
MEXUS_GOM_PLL
Fisheries
Large fish
GOM_LAR_SUV
Survey
Large fish
Indices for management procedures
JPN_LL_NEAtl2
Fisheries
Large fish
FR_AER_SUV2
Survey
Young fish
MED_LAR_SUV
Survey
Large fish
GBYP_AER_SUV_BAR
Survey
Large fish
MOR_POR_TRAP
Fisheries
Large fish

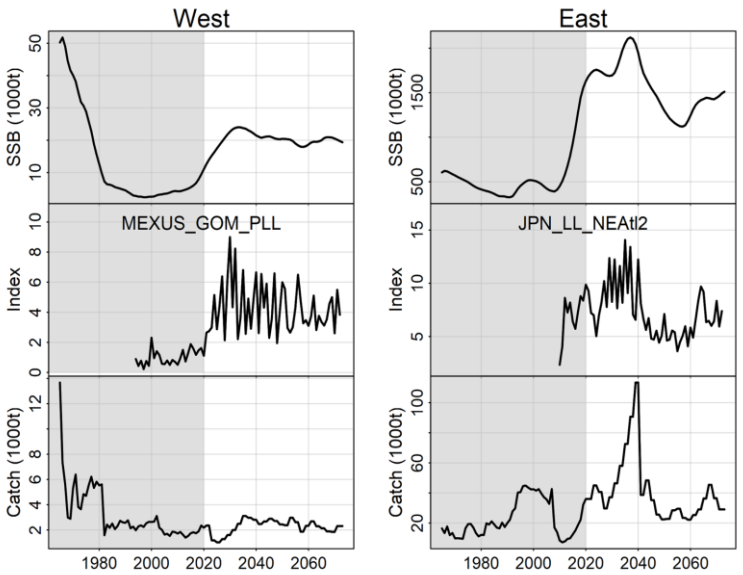
# How a BFT Management Procedure would work

Rule for West area TAC

Rule for East area




MP gives 2 catch rules, one for each area




Statistics apply to "Biological" Stock, **Status** & **Safety**

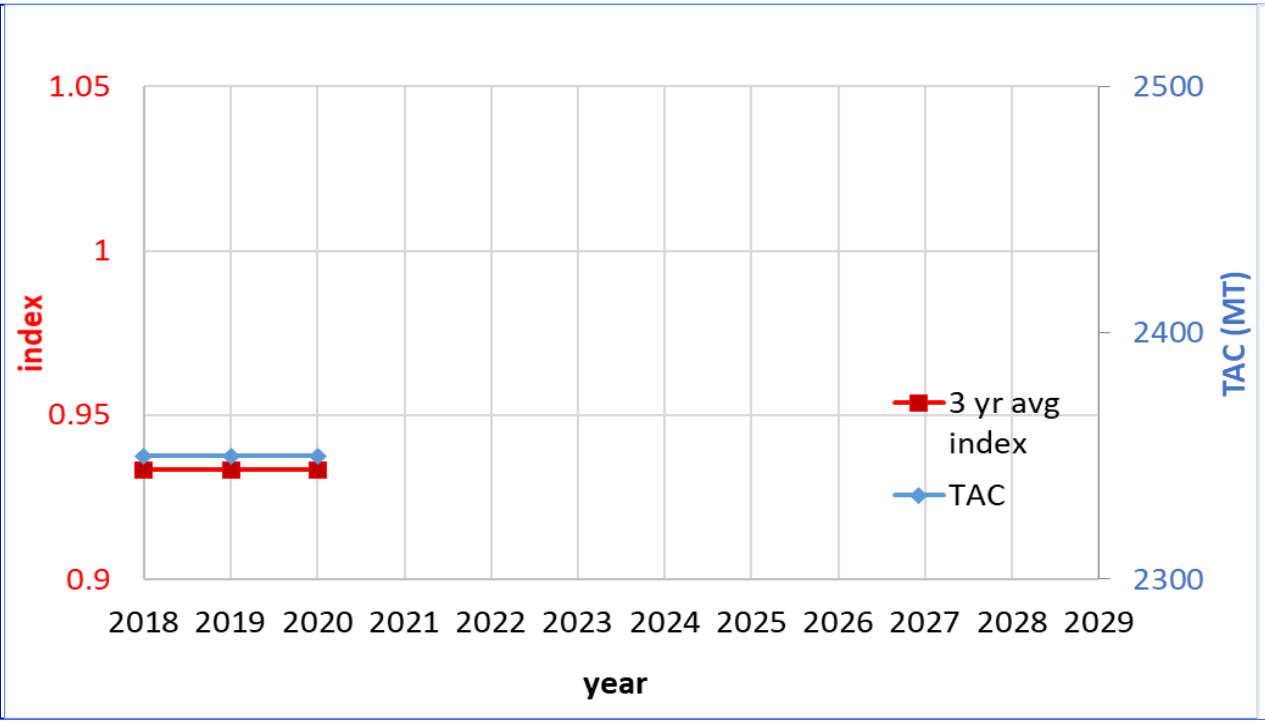
Statistics apply to Area to **Yield** & **Stability** of catch

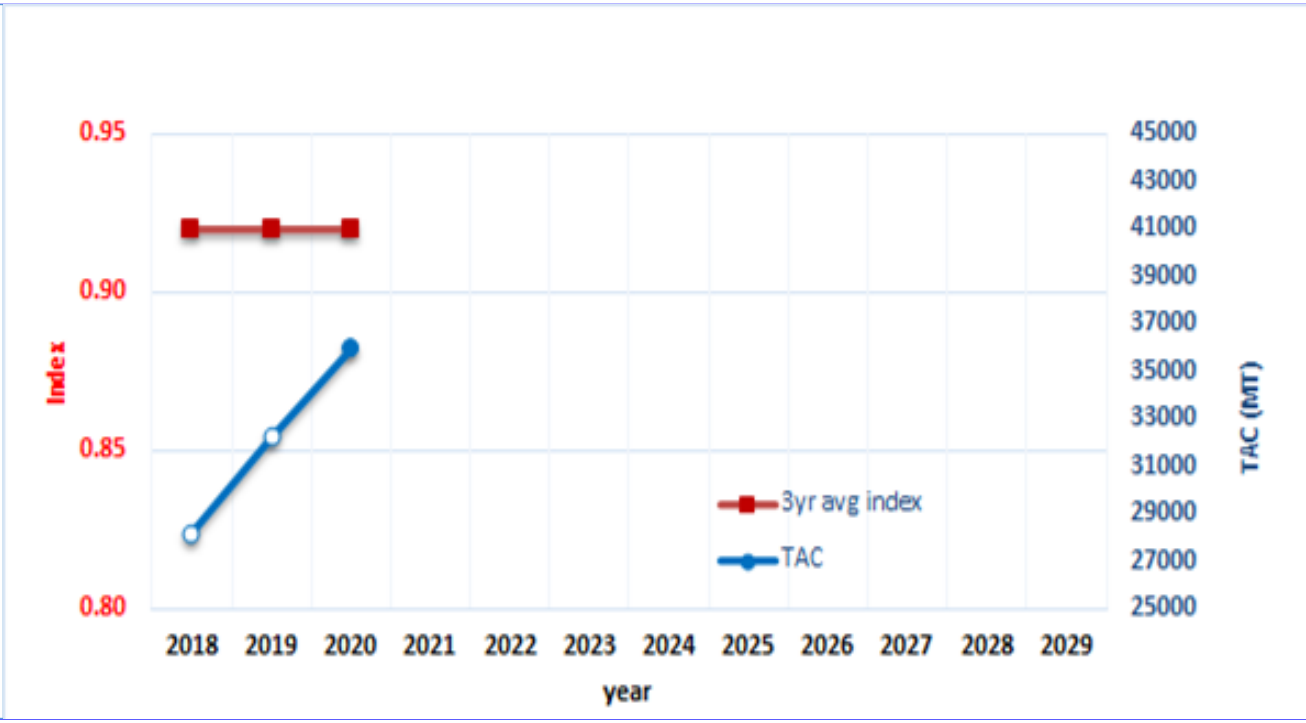
- Time series plots show historical period (shaded) and projections for one potential outcome from one example MP in a single operating model.
- MP gets index values, derives a TAC, TAC is taken from each area and stock biomass responds, resulting in new indices.
- Cycle repeats each iteration of MP application (2 years for now).
- We then compare results to operational management objectives.

# Conceptual vision for a Bluefin Management Procedure

**WEST** **EAST**

**collect 3 years of index**



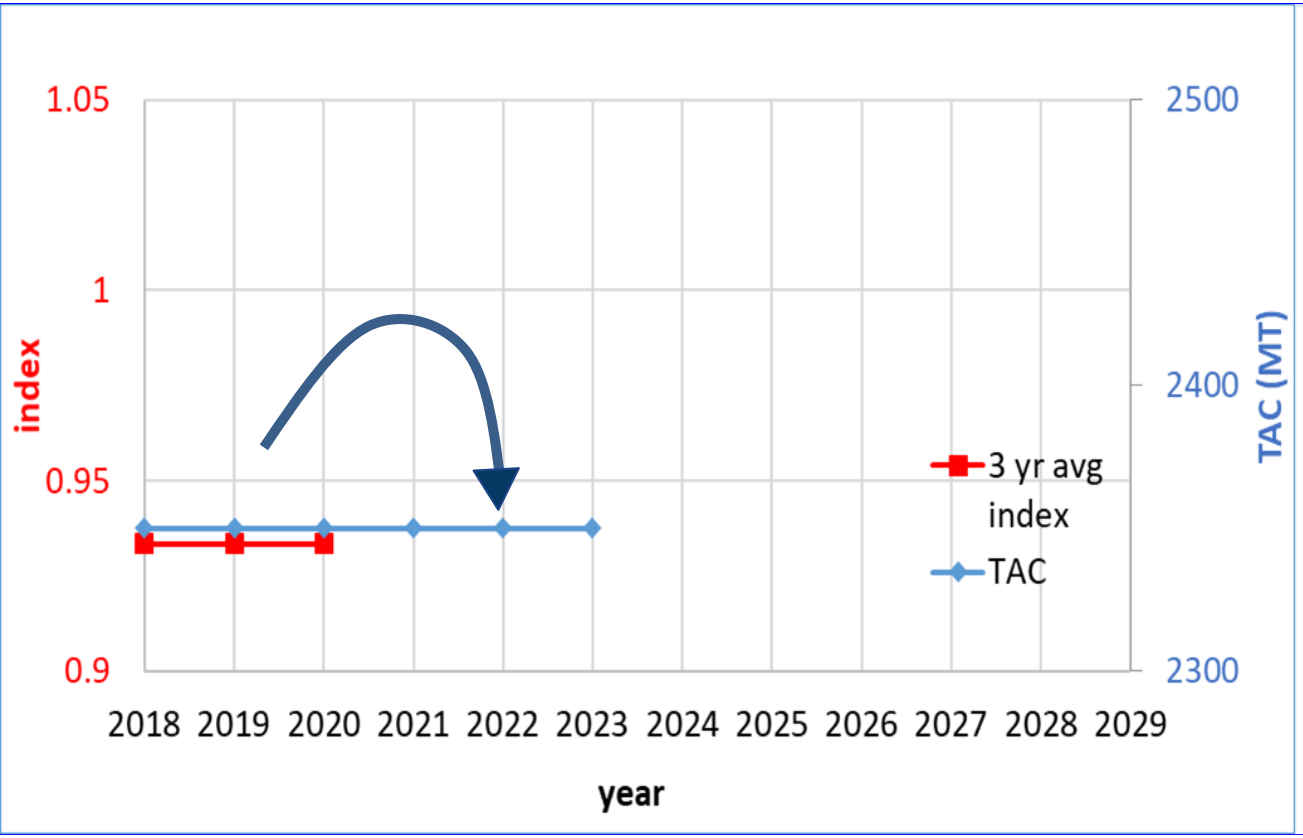



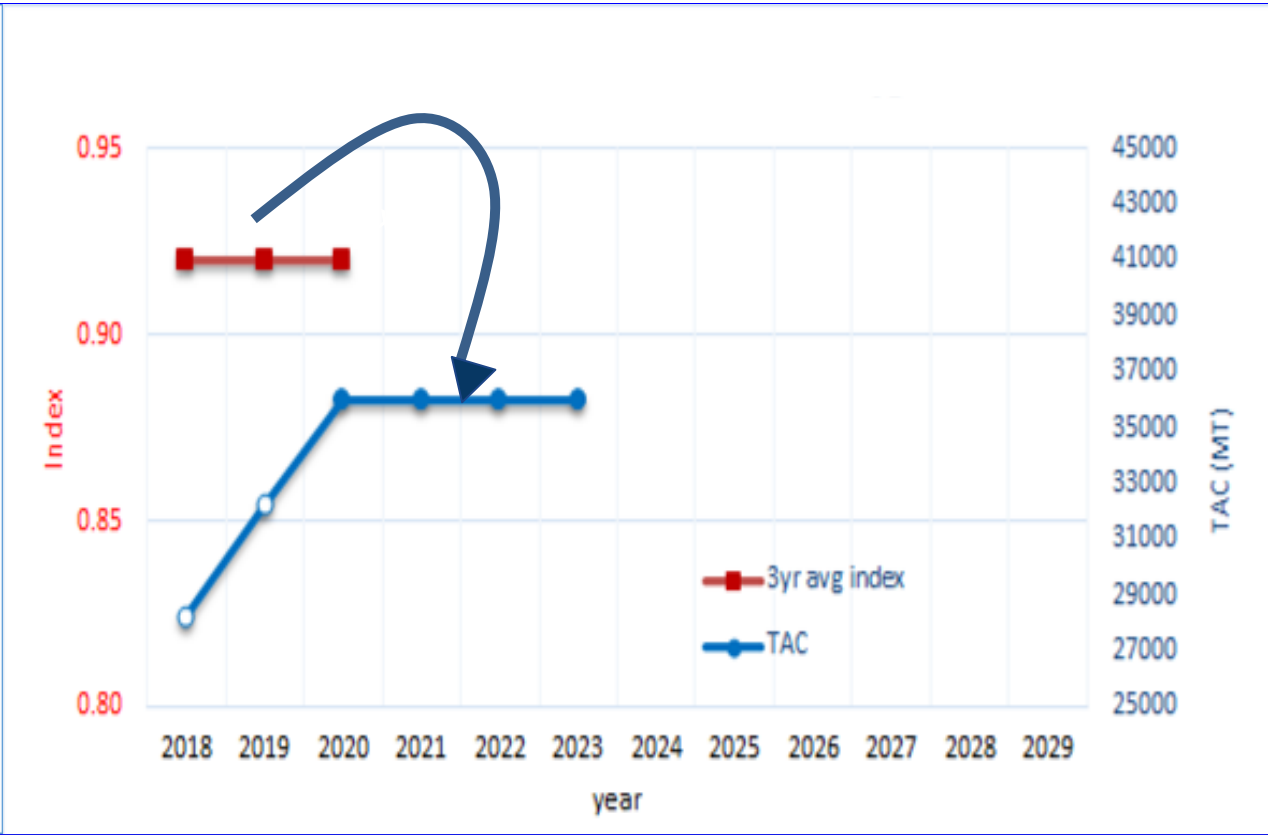

- Empirical management procedure based on index
- SCRS collects data, applies MP
- Commission sets TAC based upon MP advice
- TAC remains for *X* years

# Conceptual vision for a Bluefin Management Procedure

**WEST** **EAST**

**index constant = maintain TAC**

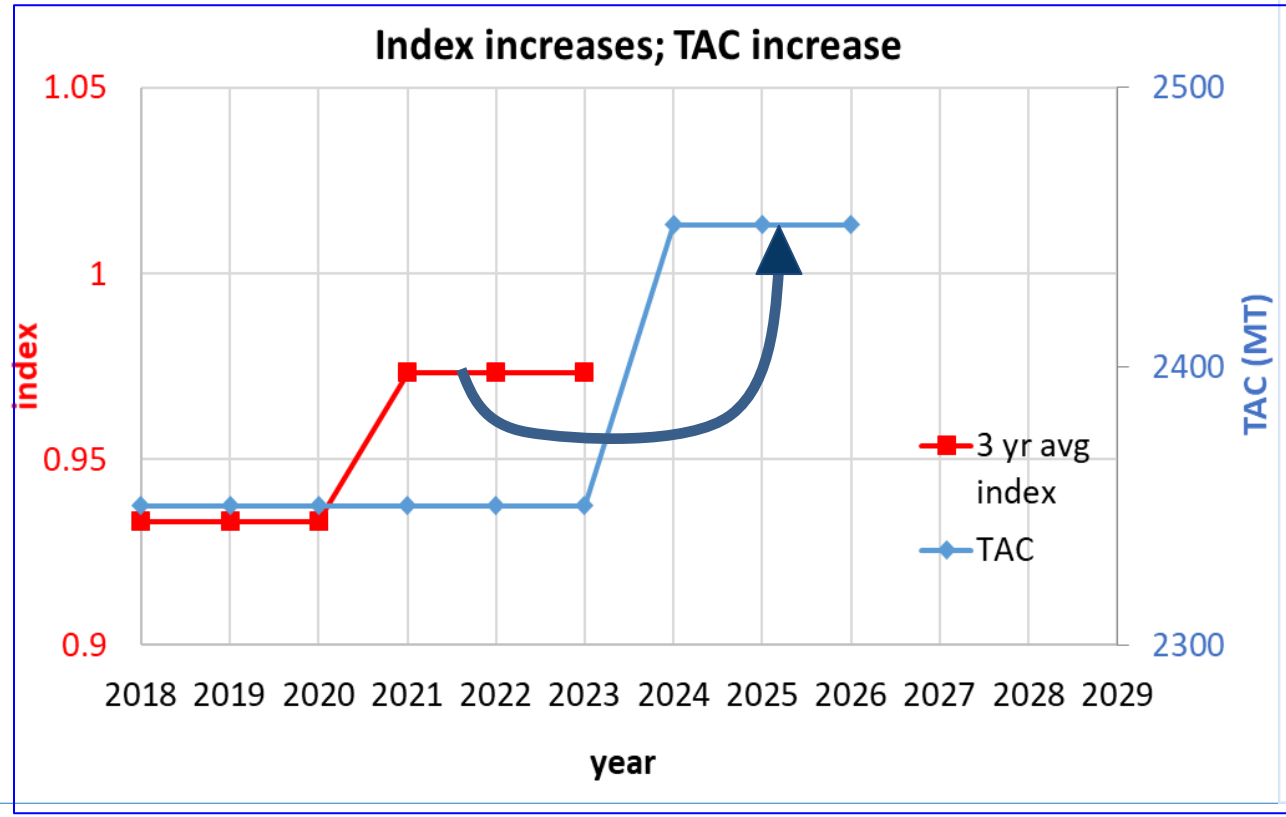


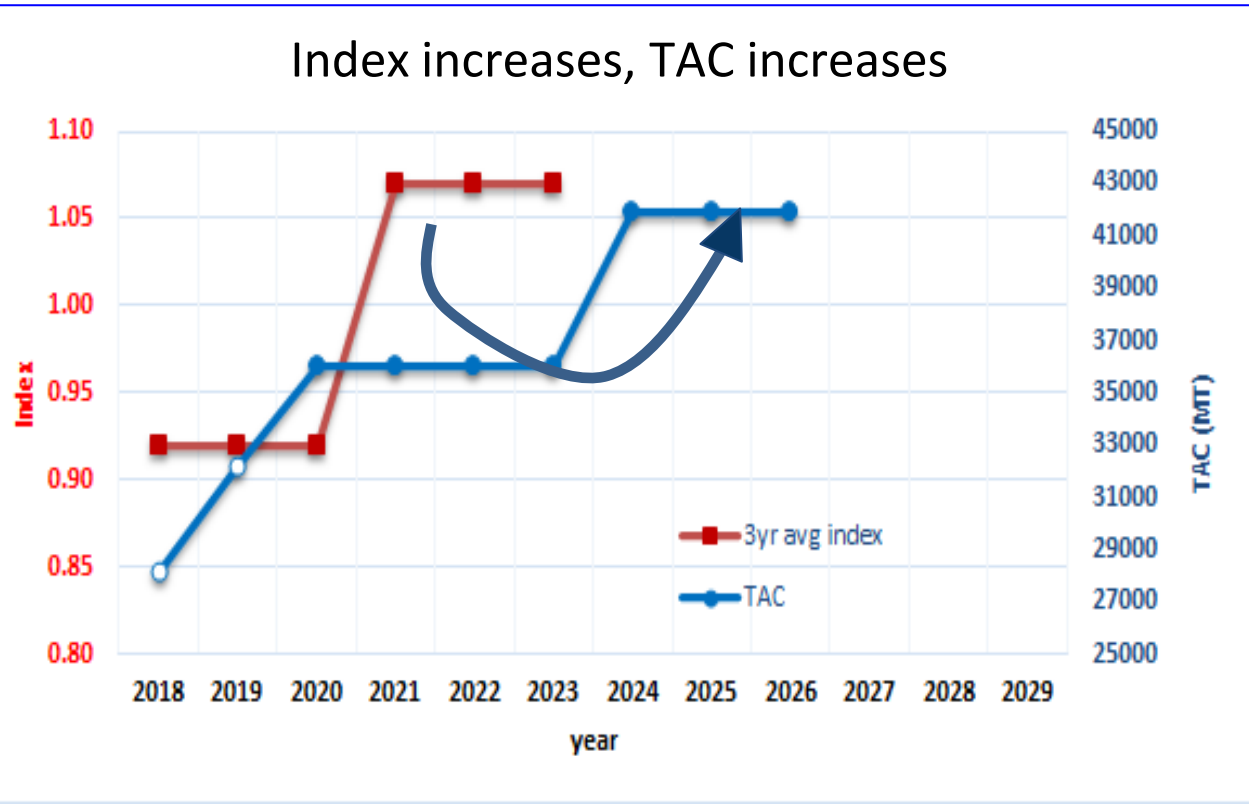

* Note that this is simply for illustration purposes and does not imply what would actually happen in the future.

# Conceptual vision for a Bluefin Management Procedure

**WEST**



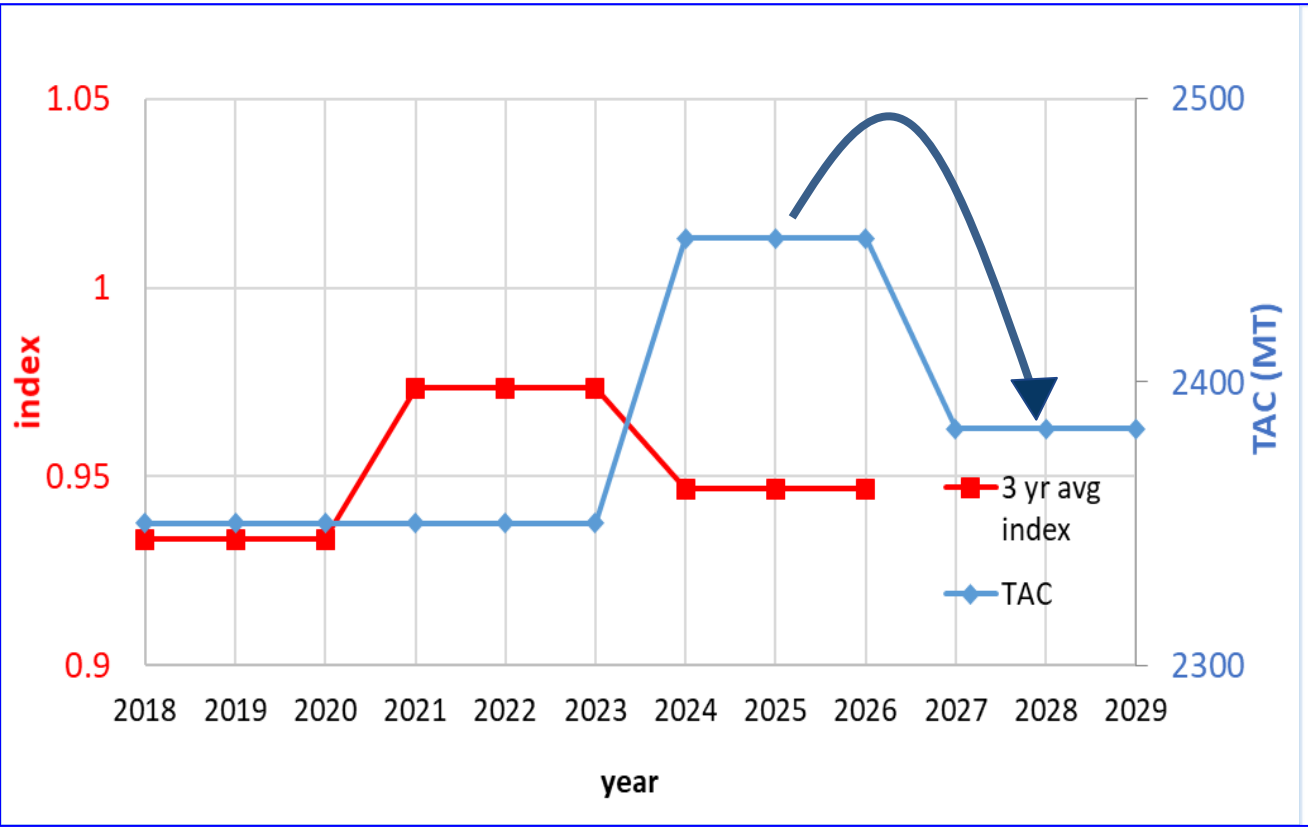

**EAST**

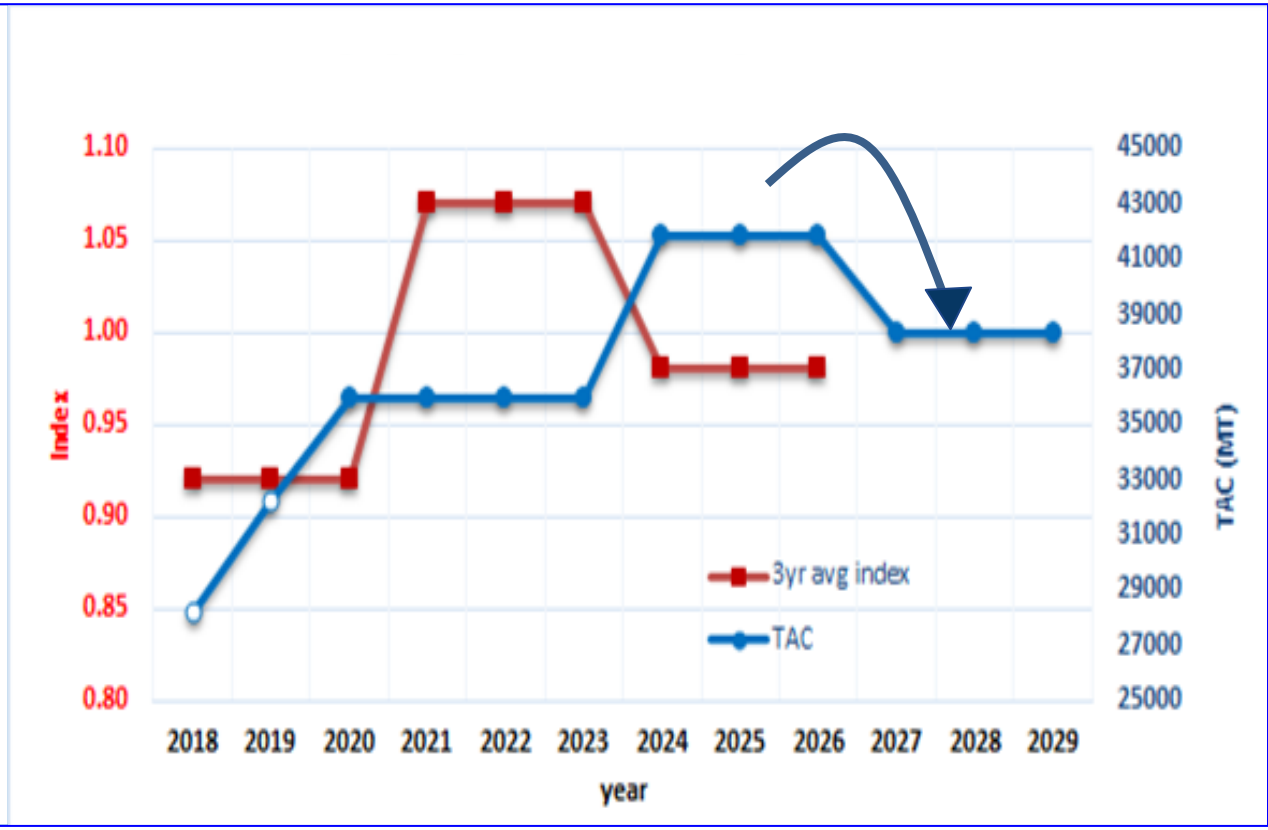


# Conceptual vision for a Bluefin Management Procedure

**WEST** **EAST**

**index decreases, TAC decreases**

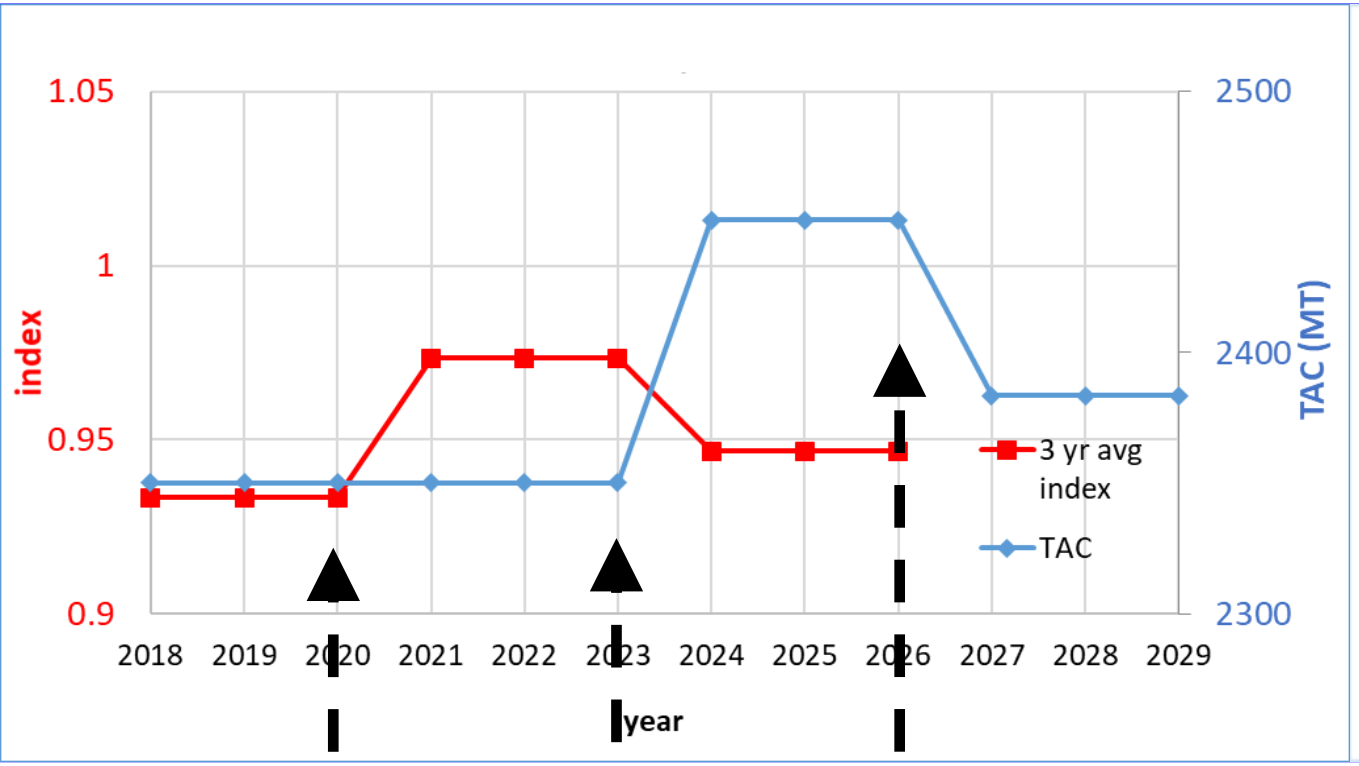


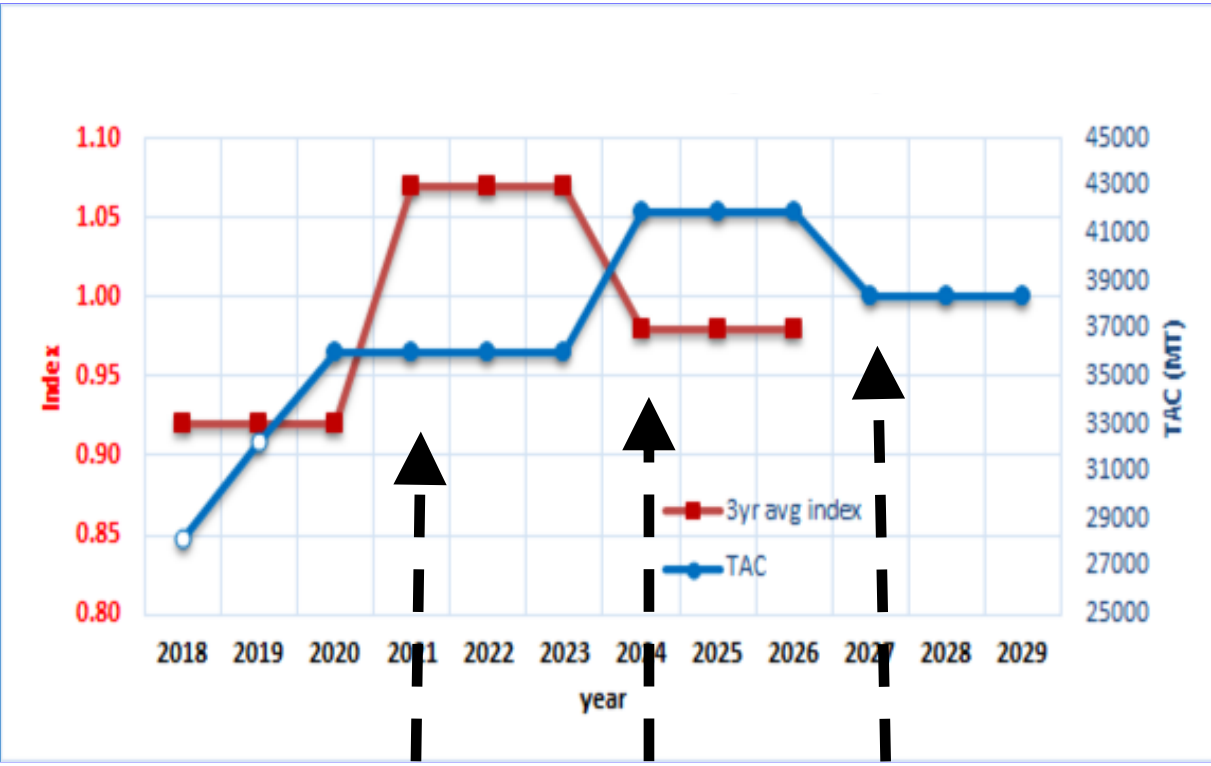



# Conceptual vision for a Bluefin Management Procedure

**WEST** **EAST**

**TAC set every three years**



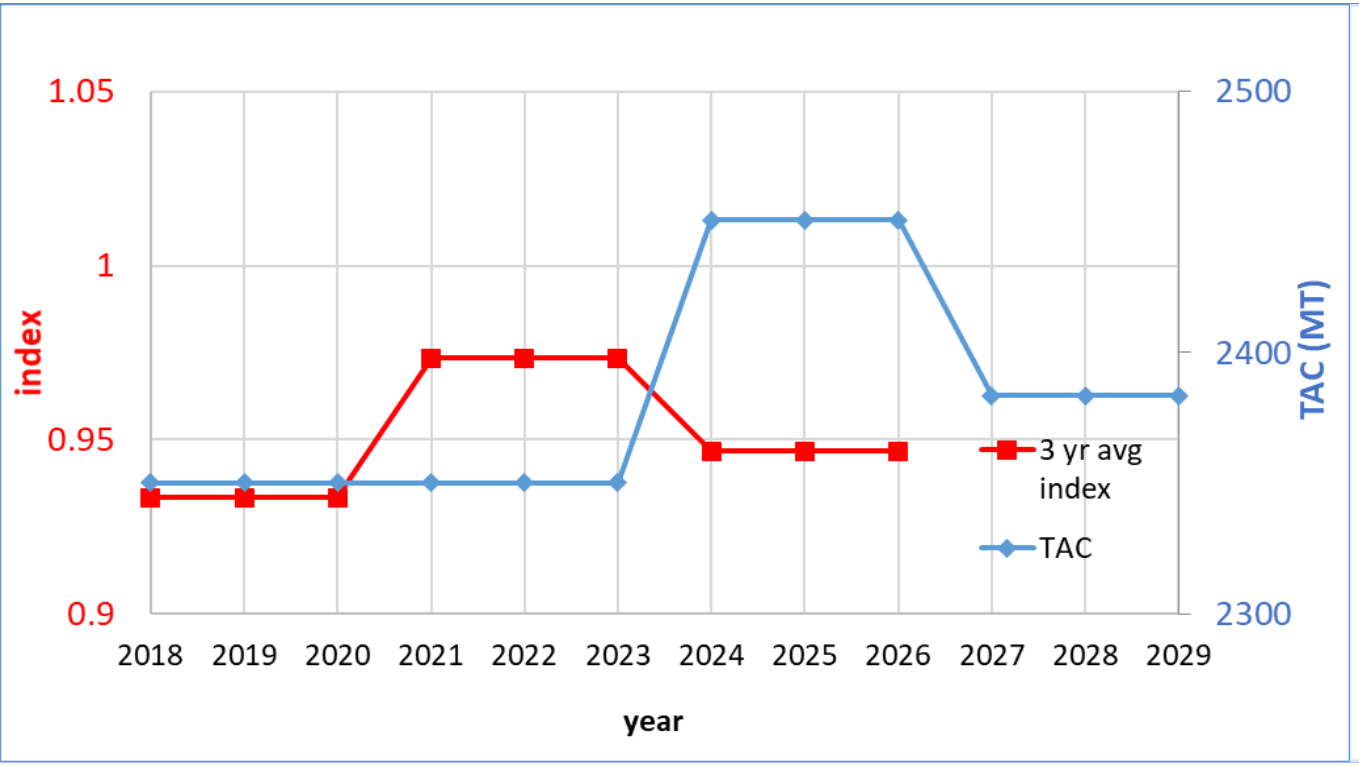



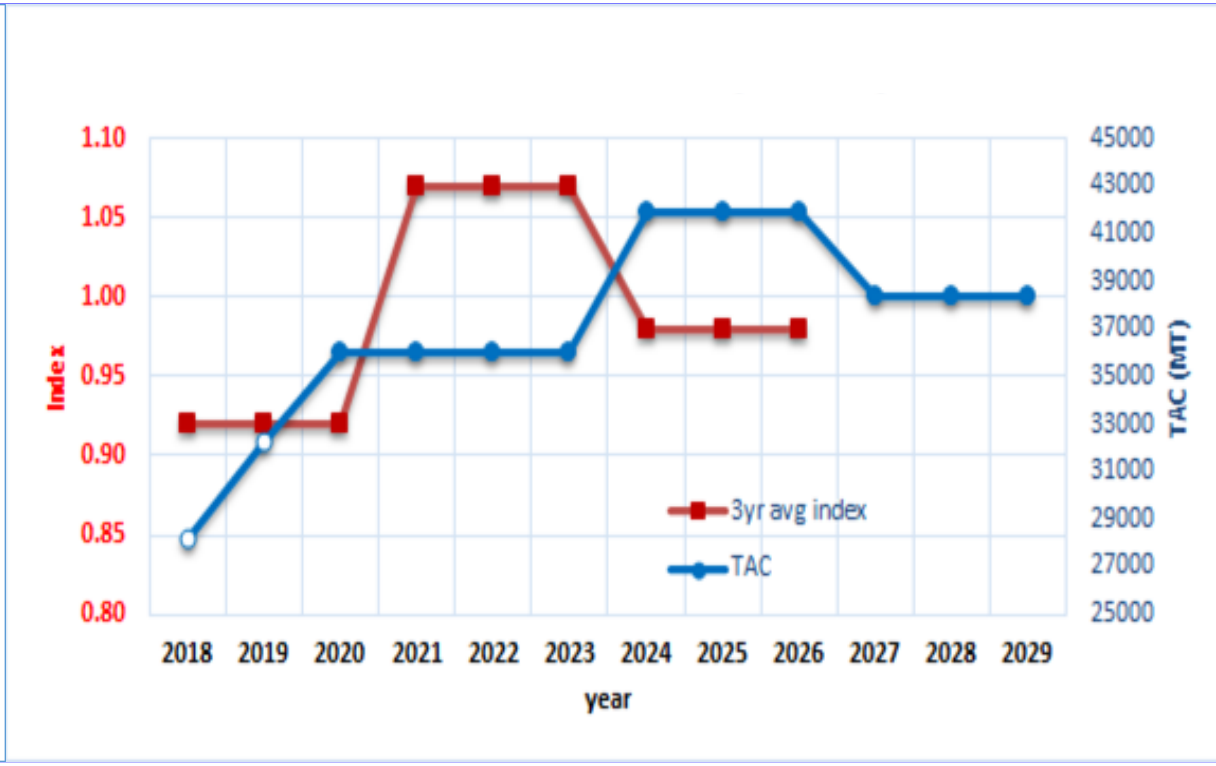

At pre-specified intervals Commission adopts a new TAC, based on pre-agreed **Management Procedure**

# Conceptual vision for a Bluefin Management Procedure

**WEST** **EAST**

**TAC set every three years**



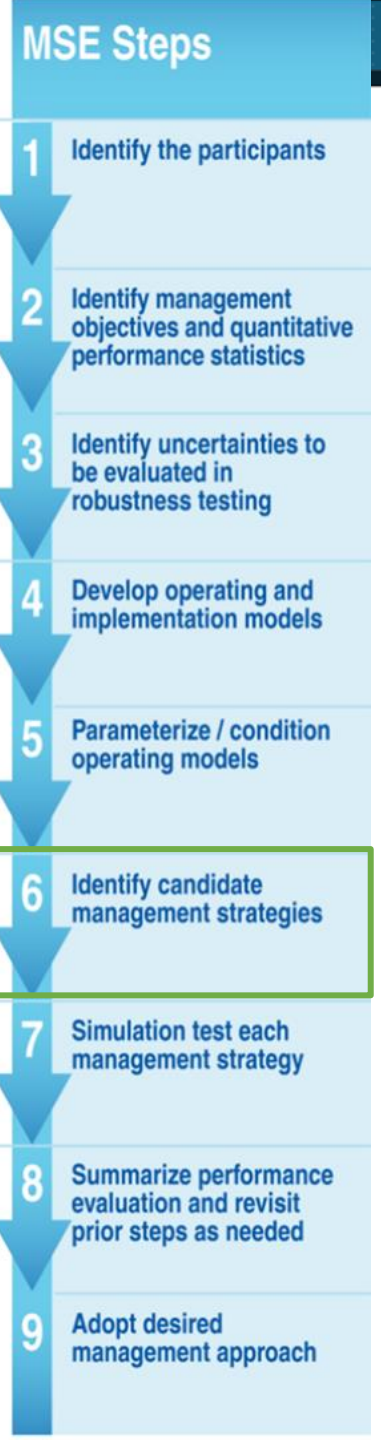



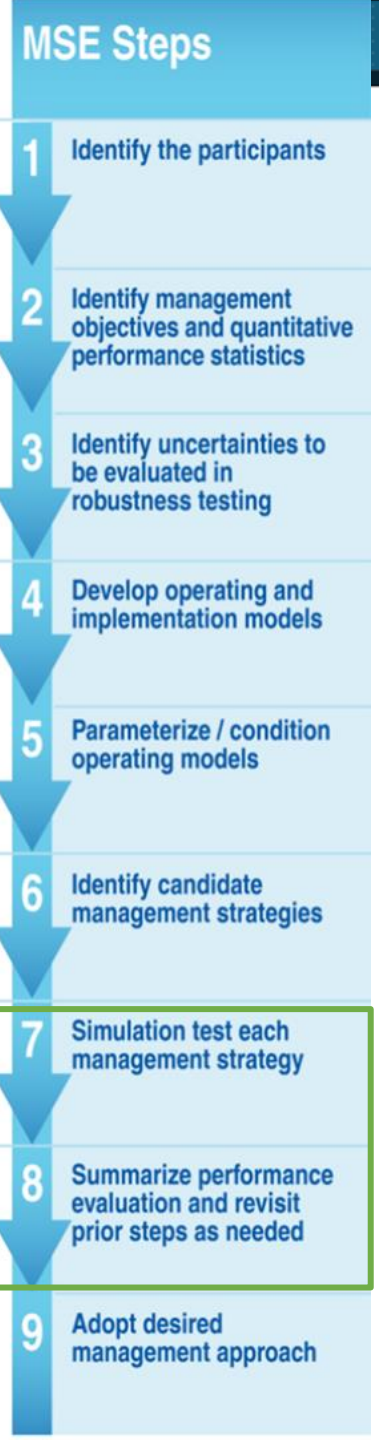

- Adopted MP would have been simulation tested
- To have high probability of achieving **Operational Management Objectives**
- Process has inherent stability, uses terminal year TAC, % change usually limited
- Routine, but less frequent stock assessments would continue

# Candidate Management Procedures (9)

| CMP | Indices used | | Formulae for calculating TACs | References |
|---|---|---|---|---|
| | EAST | WEST | | |
| FZ | FR AER SUV2<br>JPN LL NEAtl2<br>W-MED LAR SUV | US RR 66-144,<br>CAN SWNS RR<br>US-MEX GOM PLL | TACs are product of stock-specific F0.1 estimates and estimate of US-MEX GOM PLL for the West and W-MED LAR SUV for the East. | SCRS/2020/144<br>SCRS/2021/122 |
| AI | All | All | Artificial intelligence MP that fishes regional biomass at a fixed harvest rate. | SCRS/2021/028 |
| BR | FR AER SUV2<br>W-MED LAR SUV<br>MOR POR TRAP<br>JPN LL NEAtl2 | GOM LAR SUV<br>US RR 66-144<br>US-MEX GOM PLL<br>JPN LL West2<br>CAN SWNS RR | TACs set using a relative harvest rate for a reference year (2018) applied to the 2-year moving average of a combined master abundance index. | SCRS/2021/121<br>SCRS/2021/152 |
| EA | FR AER SUV2<br>W-MED LAR SUV<br>MOR POR TRAP<br>JPN LL NEAtl2 | GOM LAR SUV<br>JPN LL West2<br>US RR 66-144<br>US-MEX GOM PLL | Adjust TAC based on ratio of current and target abundance index. | SCRS/2021/032<br>SCRS/2021/P/046 |
| LW | W-MED LAR SUV | GOM LAR SUV | TAC is adjusted based on comparing current relative harvest rate to reference period (2019) relative harvest rate. | SCRS/2020/127 |
| NC | MOR POR TRAP | US-MEX GOM PLL | TAC is updated using an average of an index in recent years compared to and average in previous years. The scale of TAC increase/decrease is controlled based on the trend in catches and indices | SCRS/2021/122 |
| PW | JPN LL NEAtl2 | US-MEX GOM PLL | TAC is adjusted based on comparing current relative harvest rate to reference period (2019) relative harvest rate. | SCRS/2021/155 |
| TC | MOR POR TRAP<br>JPN LL NEAtl2<br>W-MED LAR SUV<br>GBYP AER SUV BAR | US RR 66-144 | TAC is adjusted based on $F/F_{MSY}$ and $B/B_{MSY}$. | SCRS/2020/150<br>SCRS/2020/165 |
| TN | JPN LL NEAtl2 | US RR 66-144<br>JPN LL West2 | Both area TACs calculated based on their respective JPN_LL moving averages, unless drastic drop of recruitment is detected by US_RR index. | SCRS/2020/151<br>SCRS/2021/041 |

# Management procedure questions






# Simulation test, Summarize Performance, Evaluate Trade-offs, and Revisit

# Initial results: Tradeoff between stock status and yield

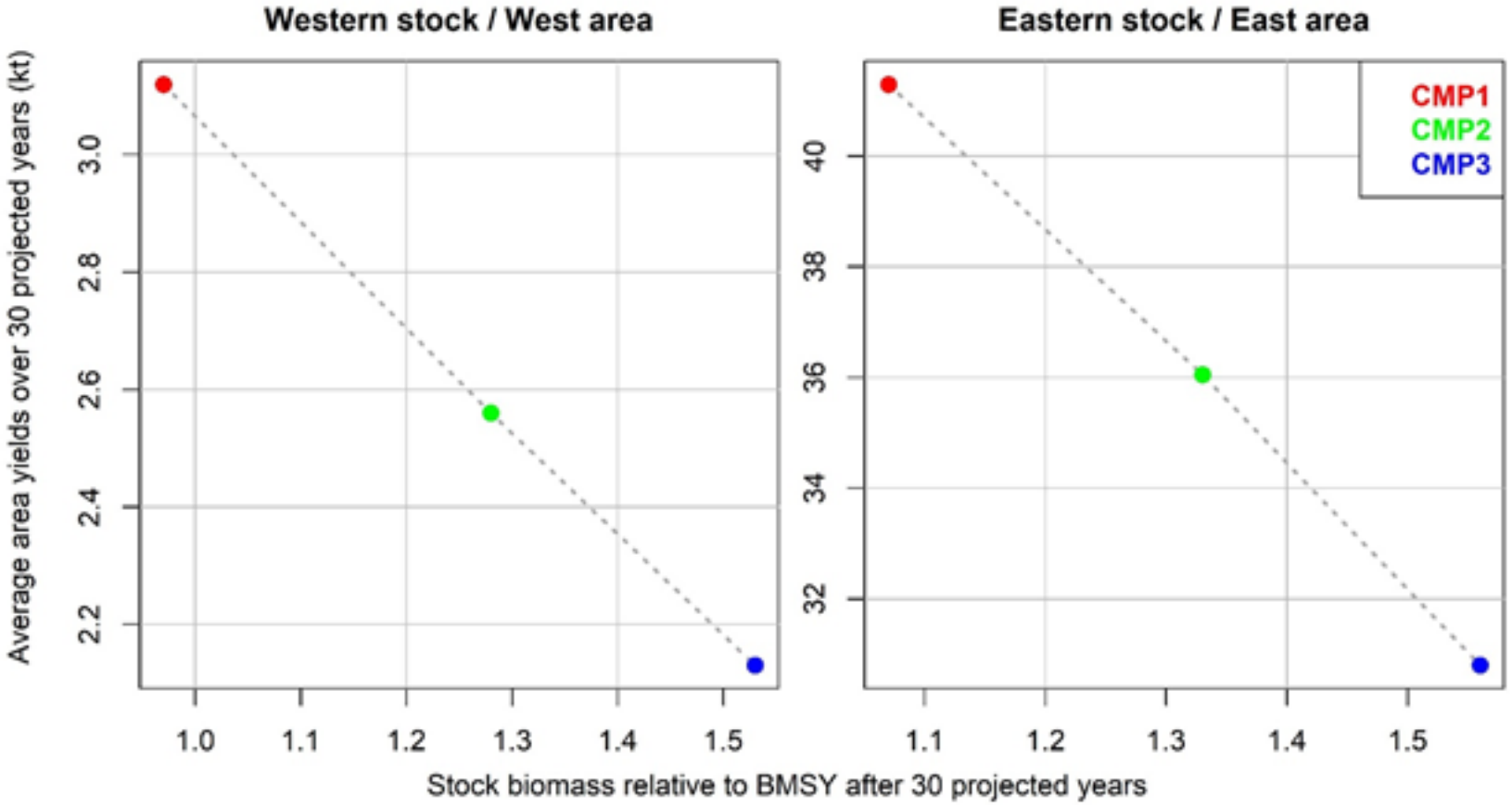
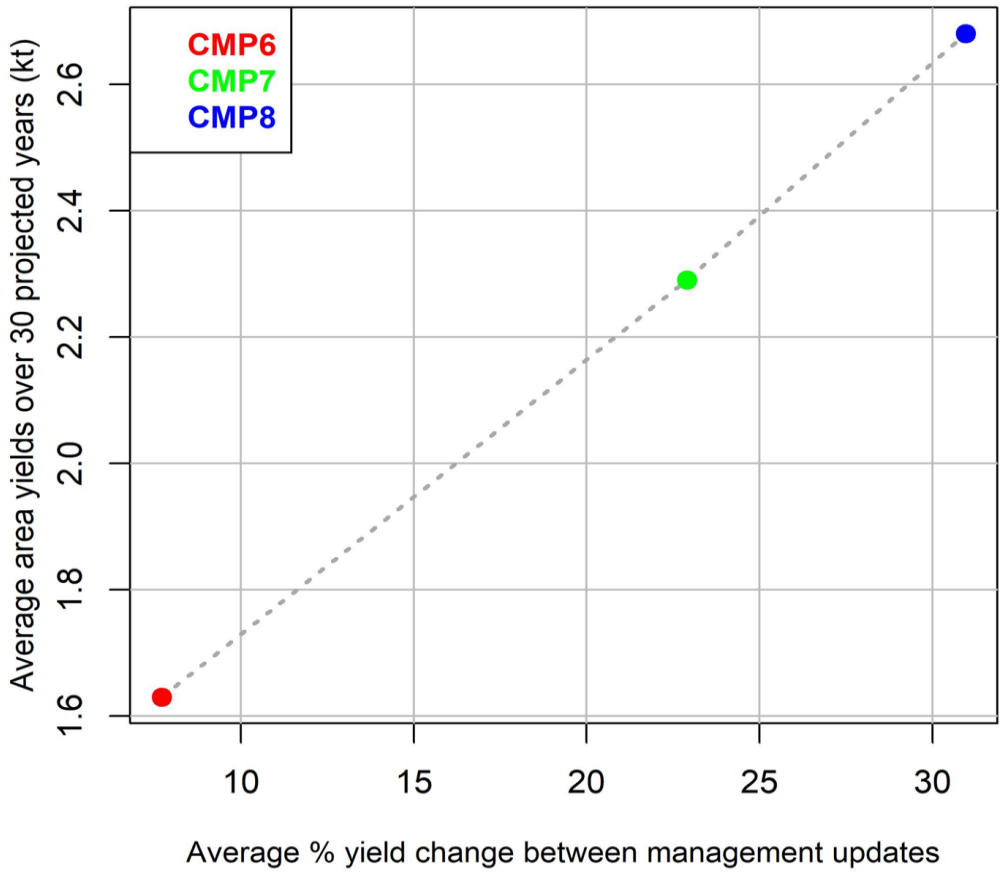



**Figure 1.** An example of the primary trade-off between yields (what is taken by fishing over 30 years, expressed as an annual average) and stock biomass (what remains in the resource after those 30 years) for three CMPs (CMP1 – red, CMP2 – green, CMP3 – blue). The left panel features western *stock* biomass (relative to $B_{MSY}$) on the horizontal axis and West *area* catch (in 1000s of tons) on the vertical axis. The right panel features eastern *stock* biomass (relative to $B_{MSY}$) on the horizontal axis and East *area* catch (in 1000s of tons) on the vertical axis. CMP1 has the highest catches but also the lowest eventual biomass relative to $B_{MSY}$. CMP3 has the lowest catches but also the highest eventual biomass relative to $B_{MSY}$. CMP2 has intermediate performance for both catch and biomass.

# Initial results: Tradeoff between yield and variability in yield



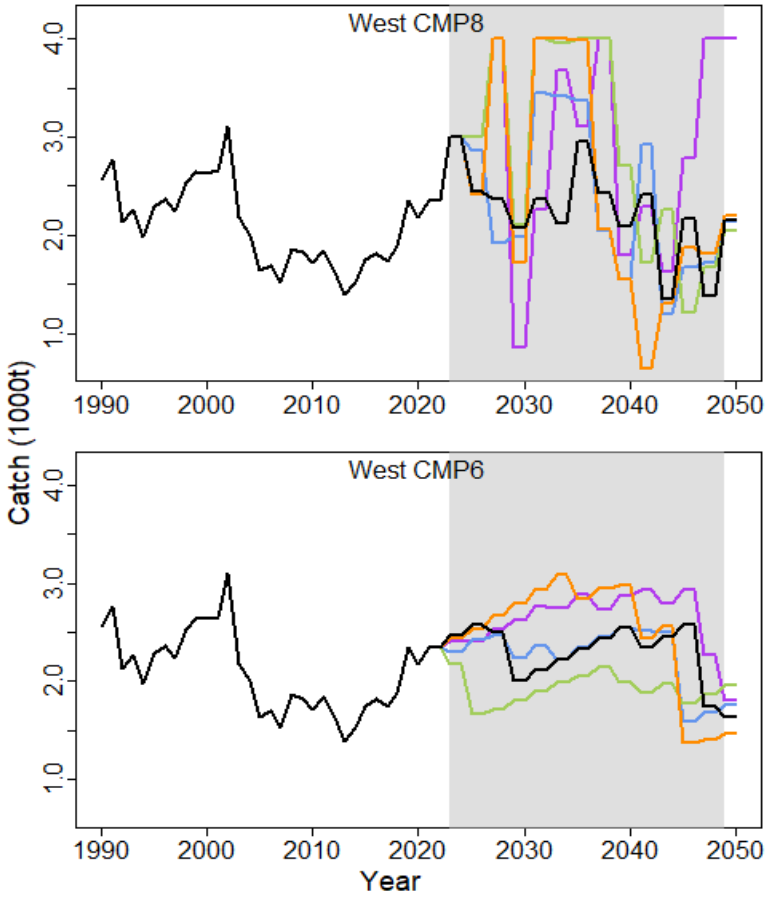
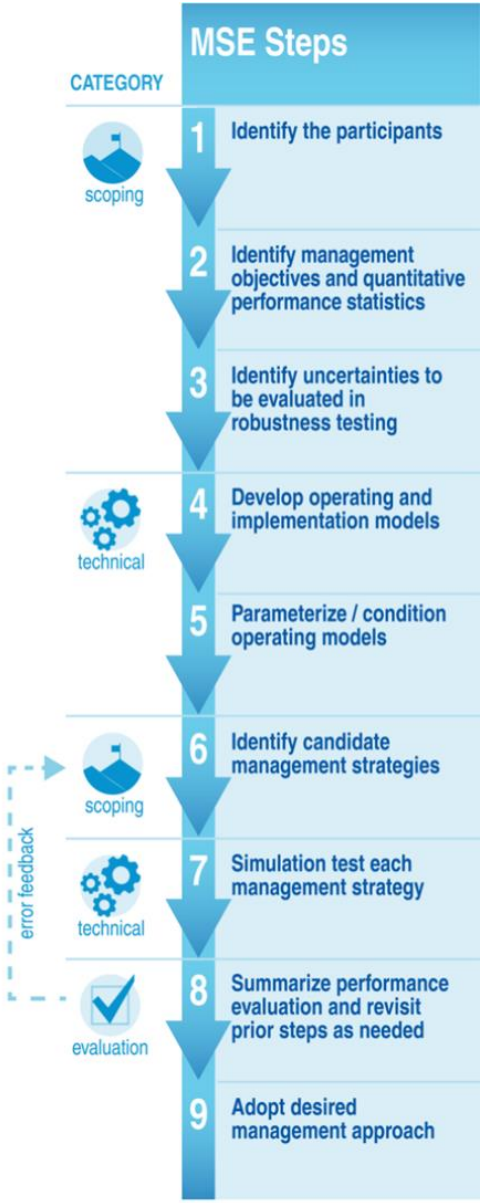




**Figure 2**. Performance trade-off between West area yields and yield variability. The left panel shows the tradeoff on average over the 30-year projection period across three CMPs (CMP6 – red, CMP7 – green, CMP8 – blue) with comparable biomass performance. Higher catches of CMP8 (upper right blue point) result in higher variability (>30%) whereas CMP6 (lower left red point) has lower but more stable catches (<10% average annual change in TAC). The right panel shows the time series of annual catches for CMP6 (bottom right) and CMP8 (top right) for the 30-year projection period (shaded), as well as the historical period. Each of the five lines depict projections from five different possible future realities (arising mainly from differences in future recruitments) generated from one operating model to display the potential variability. The tighter cluster of runs in CMP6 illustrates the greater stability in catches compared to CMP8 with its higher average yield, demonstrating the trade-off between yield and yield variability.

# Next Steps - 2022




## ICCAT Commission & SCRS workplan toward 2022 adoption

November 2021 Panel 2 MSE meeting & Commission meeting

**2022**

**March Commission Panel 2 meeting**

**May/June Panel 2 meeting**

**May/June BFT MSE TT CMP Developers incorporate P2 advice**

**Dec.-Feb. BFT MSE TT**. CMP developers incorporate Commission P2 advice

**April BFT WG intersessional**

**June/Sept BFT WG intersessional . Species Groups/SCRS.** Finalize CMPs incorporating feedback from **P2/SWGSM**

**October/November Panel 2 / November Commission**
SCRS Present to Commission CMPs, Commission adopts an interim MP at the Annual Meeting

# Draft November PA2 Agenda

1. BFT MSE essentials
2. Overview of MP implementation
3. Brief overview of candidate management procedures
4. Illustrating the tradeoff space
5. Decision points on operational management objectives & performance statistics
6. What to expect in 2022
7. Nature of SCRS/Panel 2 dialogue

# Key Discussion Points for PA2

- Acceptable ranges in tradeoffs (e.g., catch vs. biomass, catch vs. stability)
- Refinement of operational management objectives and associated performance statistics
- CMP structure (e.g., TAC setting interval, limitations on max/min TAC and catch stability)
- Reference points, including a potential limit reference point for stock size ($B_{LIM}$)

# Key MSE documents

1. BFT MSE summary 4-page
2. BFT MSE summary 1-page

# Other Resources

Harveststrategies.org

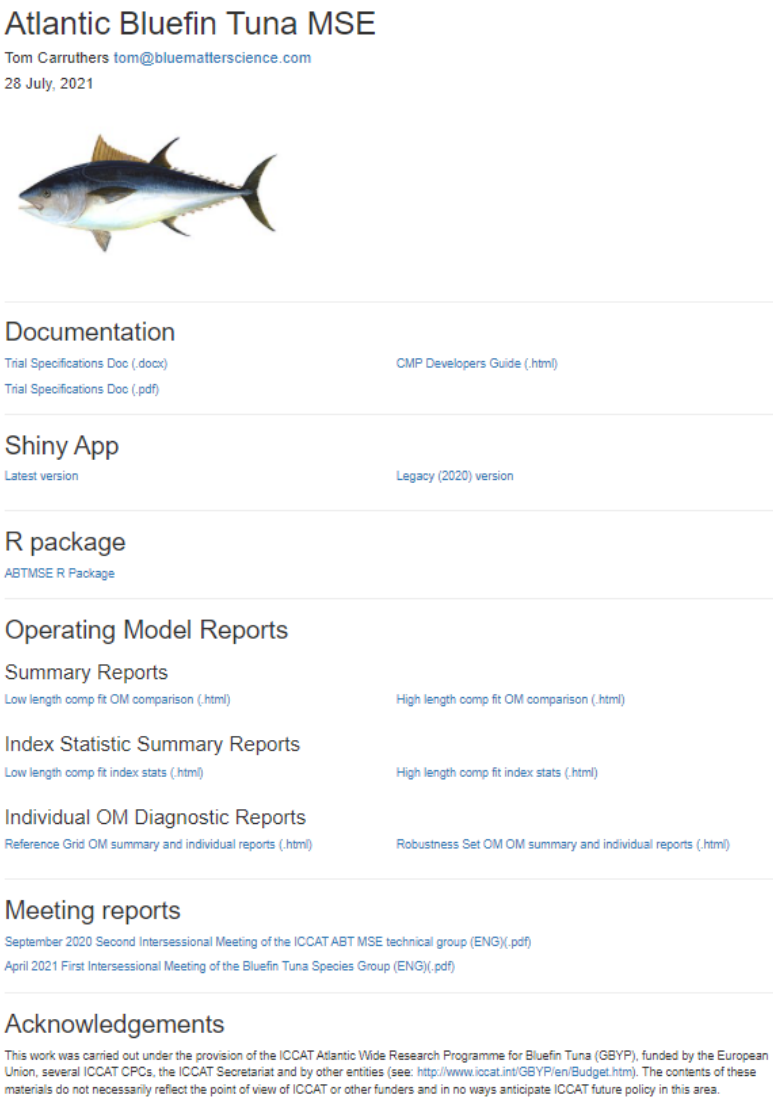
MSE outreach materials (multiple languages)








Atlantic Bluefin Tuna MSE splash page, including interactive Shiny App (Eng only)



Atlantic Bluefin Tuna MSE

Tom Carruthers tom@bluematterscience.com

28 July, 2021

Documentation

Trial Specifications Doc (.docx)
Trial Specifications Doc (.pdf)
CMP Developers Guide (.html)

Shiny App

Latest version
Legacy (2020) version

R package

ABTMSE R Package

Operating Model Reports

Summary Reports

Low length comp fit OM comparison (.html)
High length comp fit OM comparison (.html)

Index Statistic Summary Reports

Low length comp fit index stats (.html)
High length comp fit index stats (.html)

Individual OM Diagnostic Reports

Reference Grid OM summary and individual reports (.html)
Robustness Set OM OM summary and individual reports (.html)

Meeting reports

September 2020 Second Intersessional Meeting of the ICCAT ABT MSE technical group (ENG)(.pdf)
April 2021 First Intersessional Meeting of the Bluefin Tuna Species Group (ENG)(.pdf)

Acknowledgements

This work was carried out under the provision of the ICCAT Atlantic Wide Research Programme for Bluefin Tuna (GBYP), funded by the European Union, several ICCAT CPCs, the ICCAT Secretariat and by other entities (see: http://www.iccat.int/GBYP/en/Budget.htm). The contents of these materials do not necessarily reflect the point of view of ICCAT or other funders and in no ways anticipate ICCAT future policy in this area.

# Extra material

# **Appendix D.** Key terminology used in this document

**Limit reference point (LRP):** A benchmark for an indicator that defines an undesirable biological state of the stock such as the $B_{lim}$ or the biomass limit which is undesirable to be below. To keep the stock safe, the probability of violating an LRP should be very low.

**Management objectives:** Formally adopted social, economic, biological, ecosystem, and political (or other) goals for a stock and fishery. They include high-level or conceptual objectives often expressed in legislation, conventions or similar documents. They must also include operational objectives that are specific and measurable, with associated timelines. When management objectives are referenced in the context of management procedures, the latter, more specific definition applies, but sometimes conceptual objectives are adopted first (e.g., Rec. 18-03 for ABFT).

**Management procedure (MP):** Some combination of monitoring, assessment, harvest control rule and management action designed to meet the stated objectives of a fishery, and which has been simulation tested for performance and adequate robustness to uncertainties. Also known as a harvest strategy.

**Management strategy evaluation (MSE):** A simulation-based, analytical framework used to evaluate the performance of multiple management procedures relative to the pre-specified management objectives.

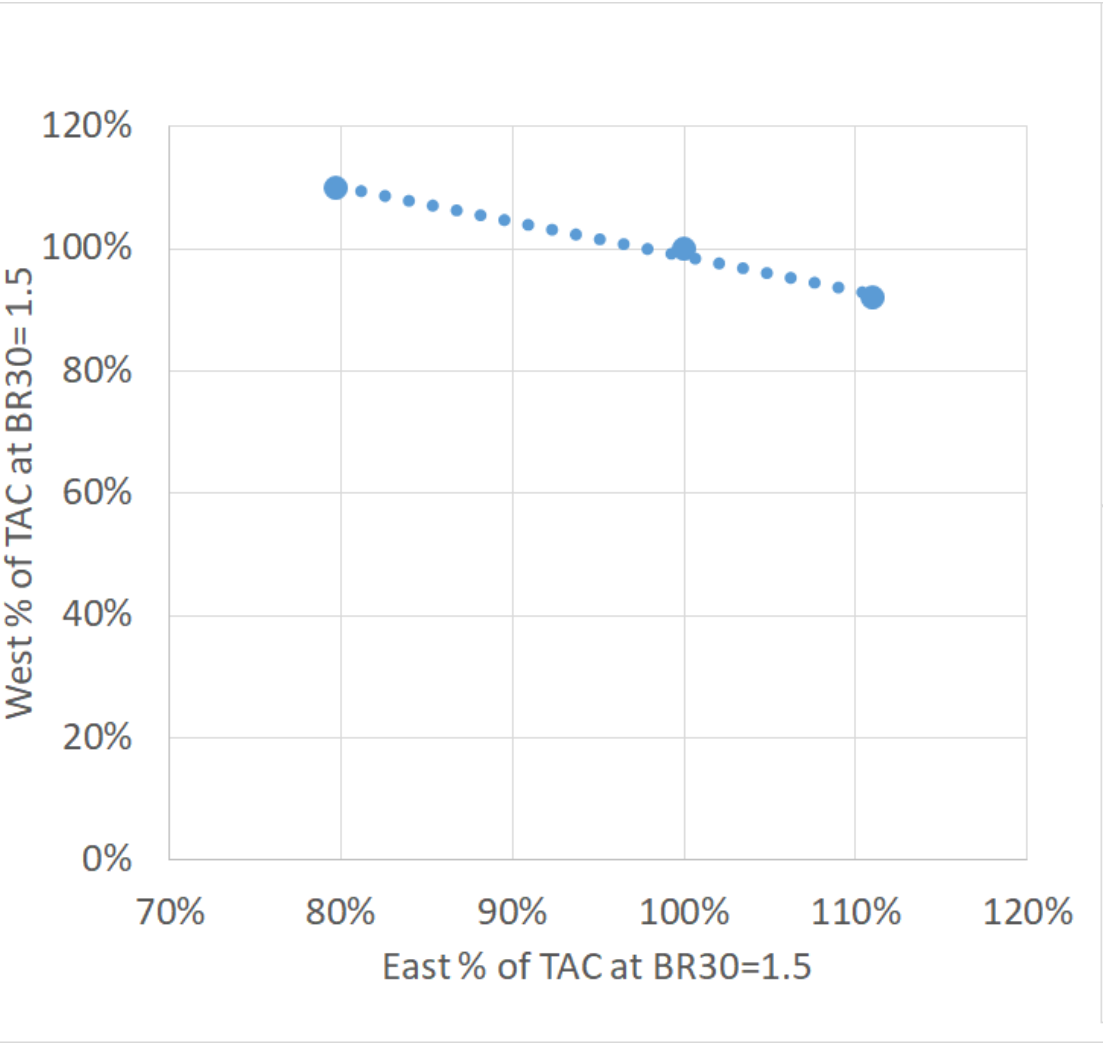
**Operating model (OM):** A model representing a plausible scenario for stock and fishery dynamics that is used to simulation test the management performance of CMPs. Multiple models will usually be considered to reflect the uncertainties about the dynamics of the resource and fishery, thereby testing the robustness of management procedures.

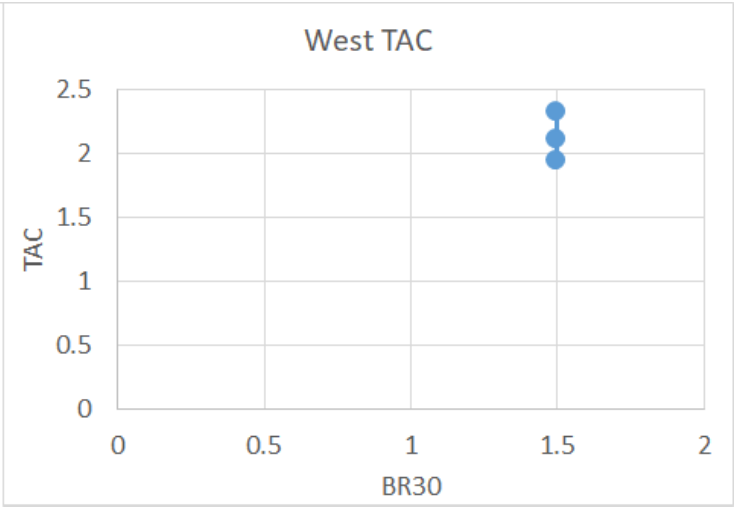
**Performance statistic:** A quantitative expression of a management objective used to evaluate how well an objective is being achieved by determining the proximity of the current value of the statistic to the objective. Also known as a performance metric or performance indicator.

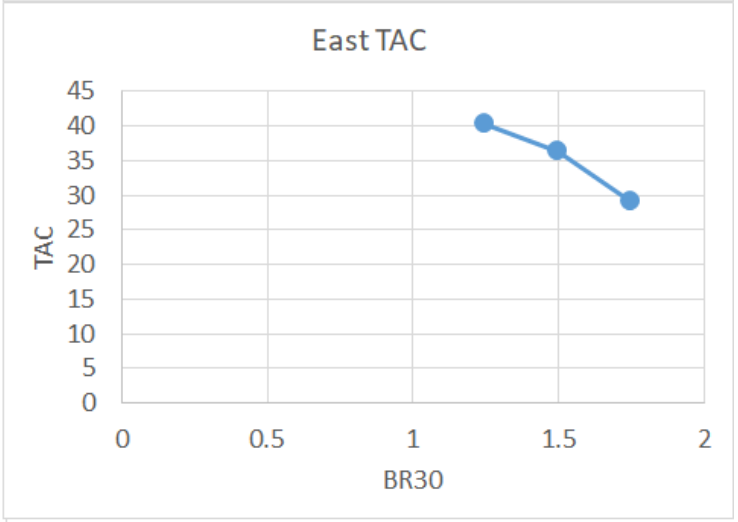
**Reference Grid:** The operating models that represent the most important uncertainties in stock and fishing dynamics, which are used as the principal basis for evaluating CMP performance. The reference operating models are specified according to factors (e.g., natural mortality rate) that have multiple levels (possible scenarios for each factor, e.g., high / low natural mortality rate). Reference operating models are organized in a usually fully crossed orthogonal ‘grid’ of all factors and levels.

**Robustness Set:** Other potentially important uncertainties in stock and fishing dynamics may be included in a Robustness Set of operating models that provide additional tests of CMP performance robustness. They can be used to further discriminate between CMPs. Compared to the Reference Grid operating models, the Robustness Set models will be typically less plausible and/or influential on performance.

# Initial results: Tradeoff between East and West




One natural concern with mixed stock fisheries is that what happens with one stock affects the other.

With many eastern fish in west, a different TAC for the east area will have some impact on the west TAC.

Indications thus far are that this effect will probably not be too large.

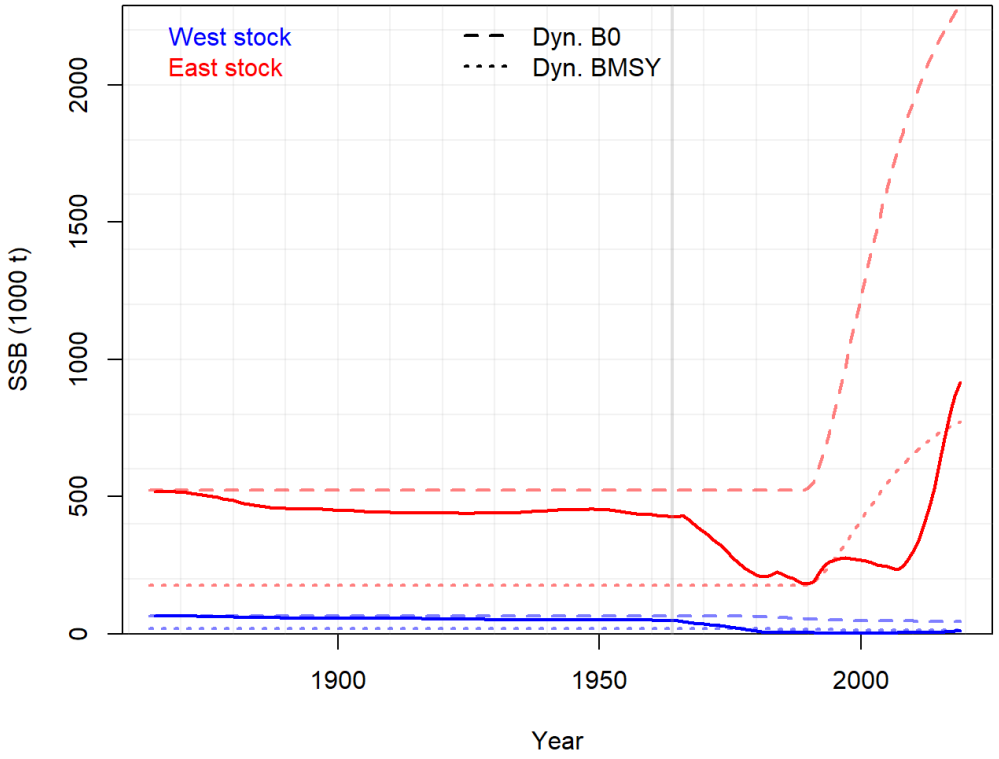
In this figure, for one example CMP, we see that the main sensitivity lies on the original East yield vs East status.

West status is fixed at the same BR30 but it is East yield that varies most, with much less sensitivity on West yield.

We will expand on this further as CMPs are refined during 2022

# Dynamic Bmsy:

Dynamic unfished spawning biomass (Dyn. B0) is calculated using year-specific estimates of unfished recruitment (depending on which R0 phase the model is in) assuming that there was zero fishing (ie it lags shifts in productivity). Dynamic BMSY is a fixed fraction of B0 based on the most recent estimates of BMSY relative to unfished (the steepness parameter assumed for 2016). Since in some operating models, R0 is changing over time, the maximum achievable level of stock biomass is also changing and keeping track of dynamic B0 provide a realistic yardstick for evaluating management performance.




This is for OM1 which has a regime shift where the Eastern stock recruitment shifts from medium to high and the Western stock recruitment shifts from high to low.

The resulting B0 and Bmsy are dynamic and shift commensurately but with a lag