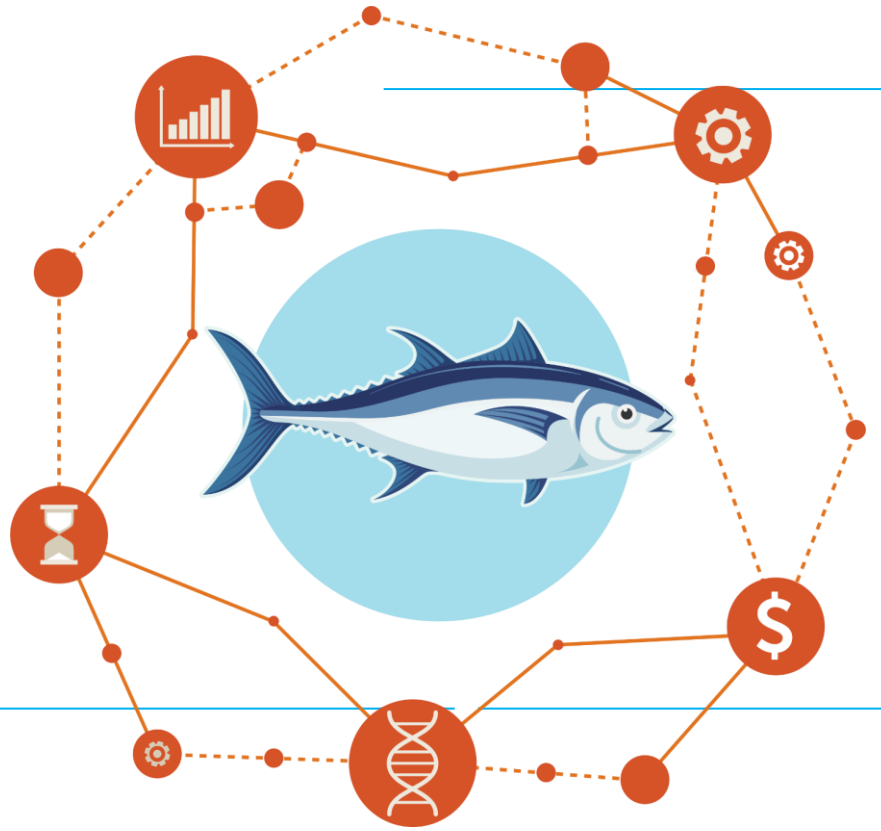


BFT Management Strategy Evaluation (MSE)

November 12, 2021

References

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

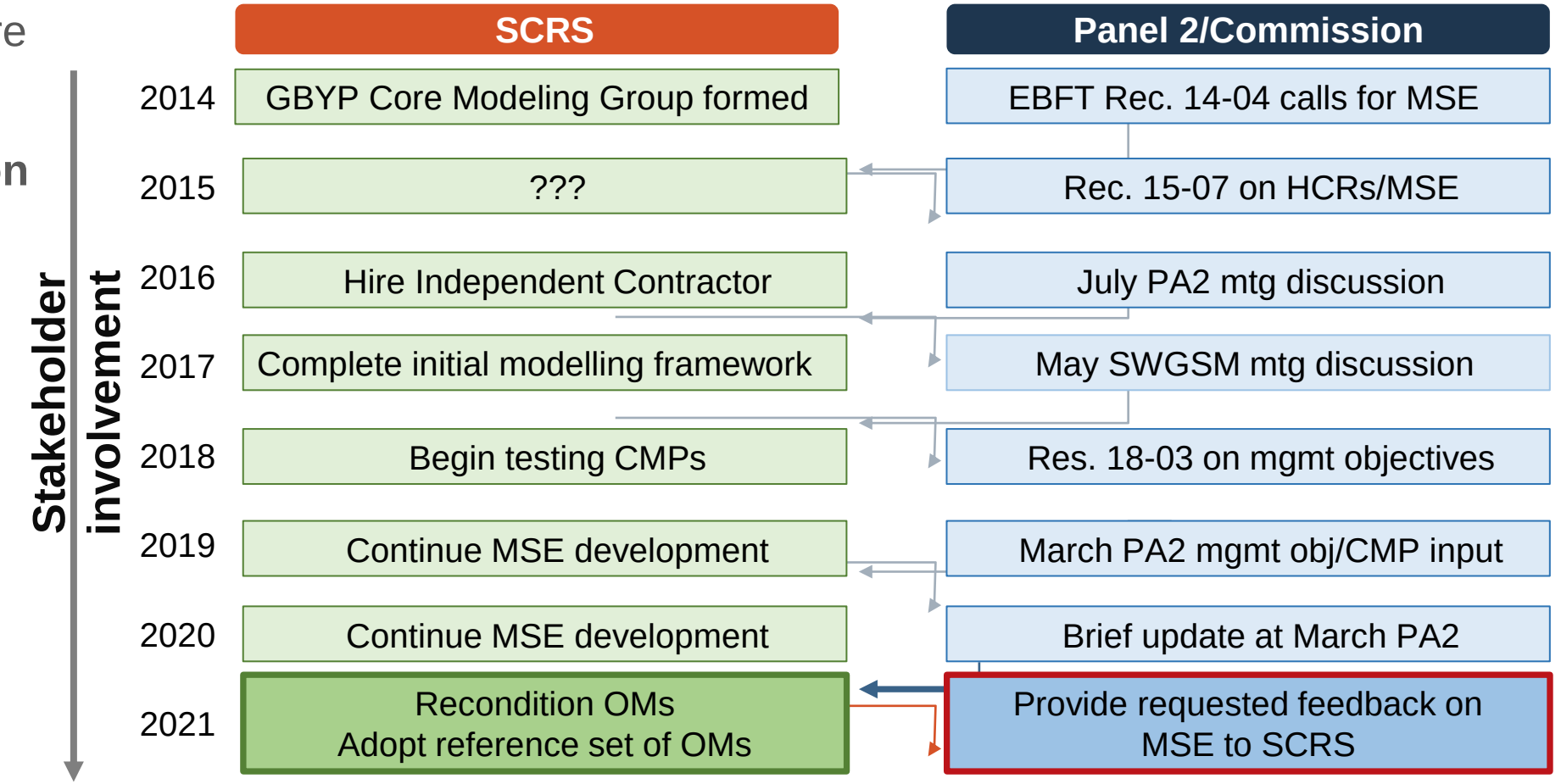
Presentation Overview (follows PA2 agenda):

4. BFT MSE essentials
5. Overview of MP implementation
6. Overview of existing CMP structure and the key role of performance
7. Illustrating the trade-off space and acceptable ranges in trade-offs
8. Decision points on operational management objectives & performance statistics
9. Future work

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.

Timeline of ABFT MSE Development

Management procedure development is a **dynamic collaboration** between scientists, managers, and other stakeholders



Current Progress:

- SCRS has adopted 48 reference OMs as a reference set and plausibility weighted them.
- SCRS has defined an additional 12 Robustness OMs.
- 9 CMPs are under development.
- On track to work with Panel 2 to refine CMPs during the course of 2022.
- Goal is to provide 2-3 CMPs that likely span the key trade-off space range to Commission in 2022 for 2023 TAC.

Next Steps for 2022:

- Increase communication among all participants – understanding of MSE, key decision points and trade-offs and how a CMP will work
- During 2022 in collaboration with Panel 2:

  - refine management objectives and performance indicators

  - refine, test and eventually select top ranking CMPs

Adhere to a rather enthusiastic, but feasible workplan.

What is Management Strategy Evaluation?

- **Management Strategy Evaluation (MSE)** 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 (MOs):** Formally adopted goals for the fishery.

A Brief Overview of Management Procedures

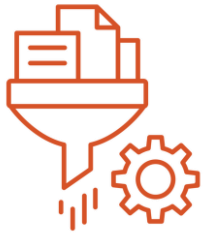
- A **pre-agreed framework** for making management decisions

- Evaluated and selected using **MSE**

- Three main elements

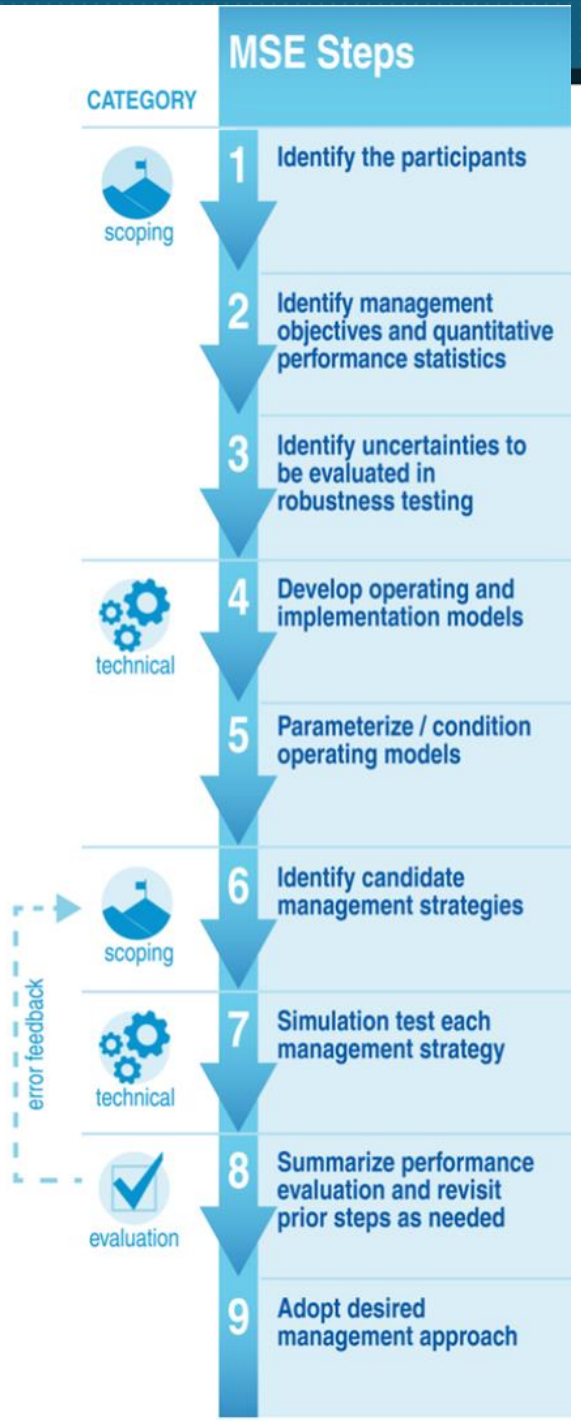
Monitoring data with collection plan

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



Harvest control rule
(HCR)

Diagram of MSE Process



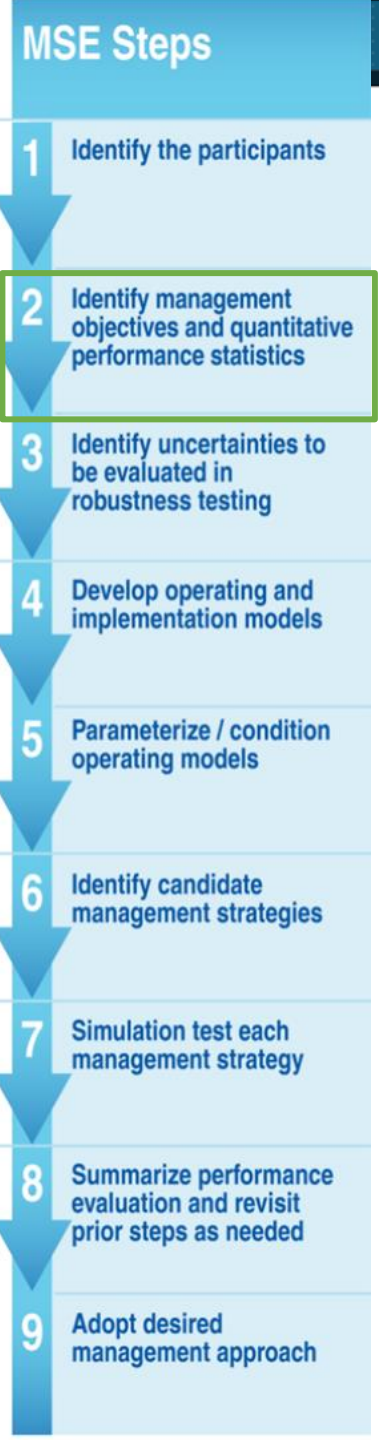
← Management objectives

← Operating models

← Candidate Management procedures

★ We are here

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 [__]%

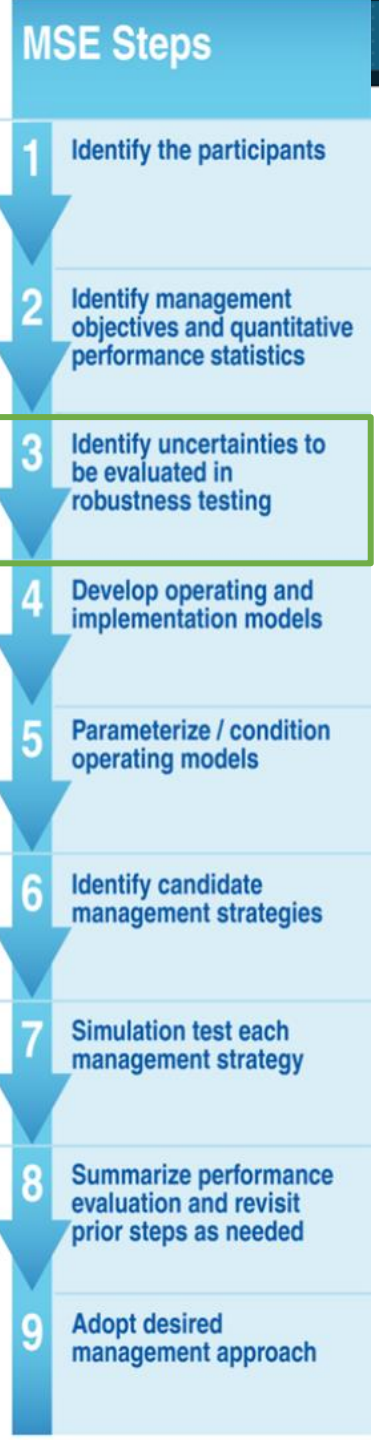
- **LD** – Lowest depletion (i.e., SSB relative to dynamic SSB_0[2]) over 30-year projection period

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 almost always be considered to reflect the uncertainties about the dynamics of the resource and fishery, thereby testing the robustness of management procedures to these uncertainties.

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

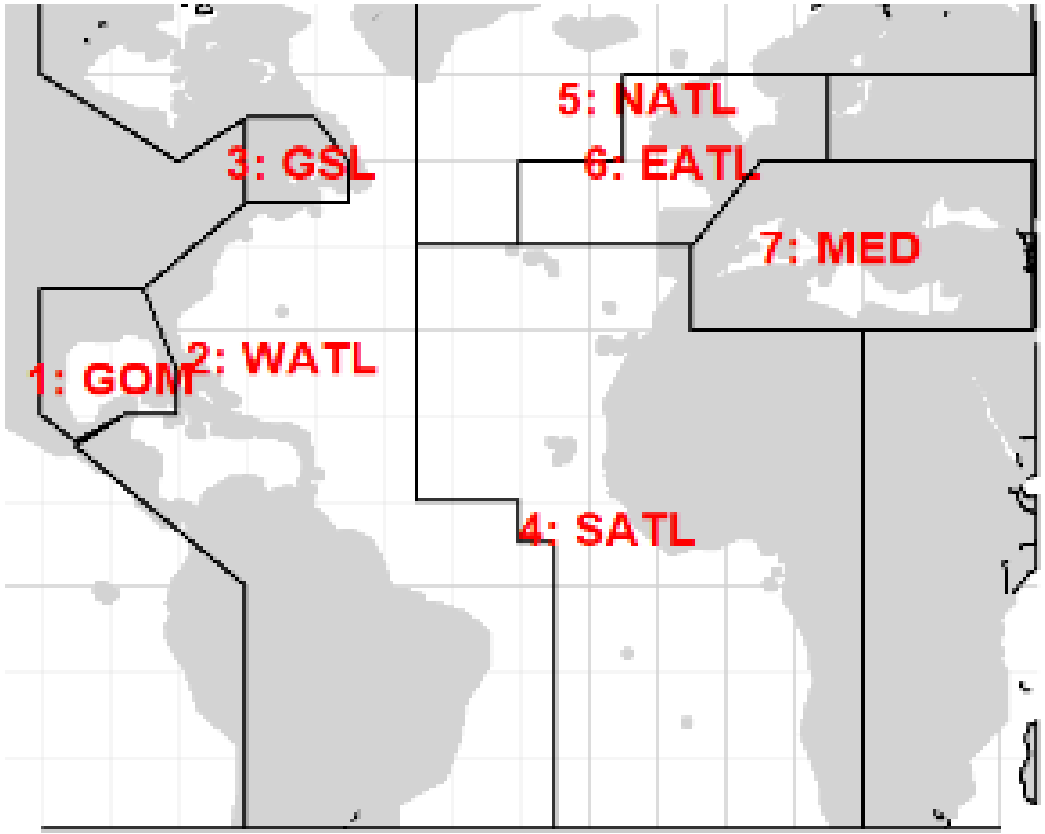
Robustness set: unlikely but still possible scenarios or hypotheses. What-if and worst-case scenarios.

Reference set: screen all MPs

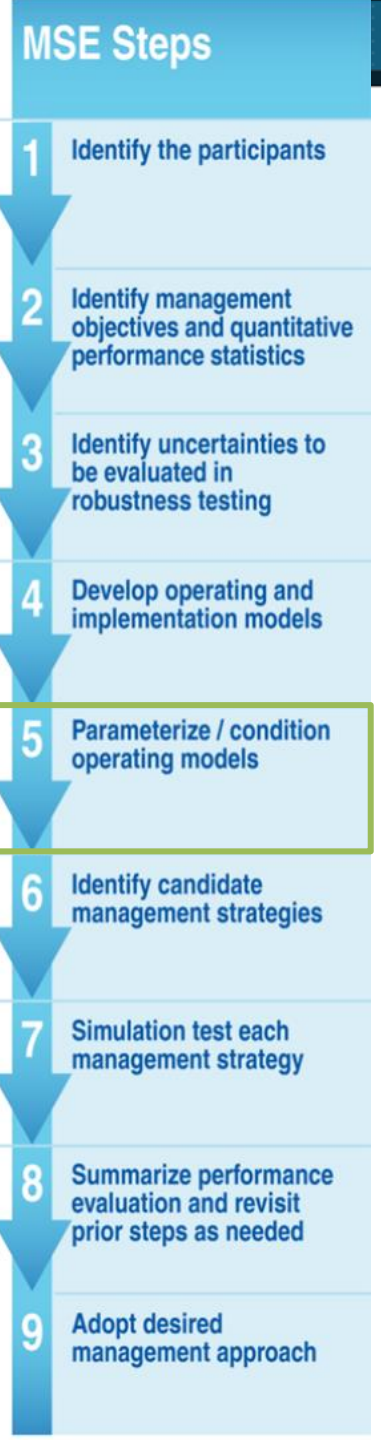
Robustness set: screen top-performing MPs

Operating Model structure

- Spatial definitions



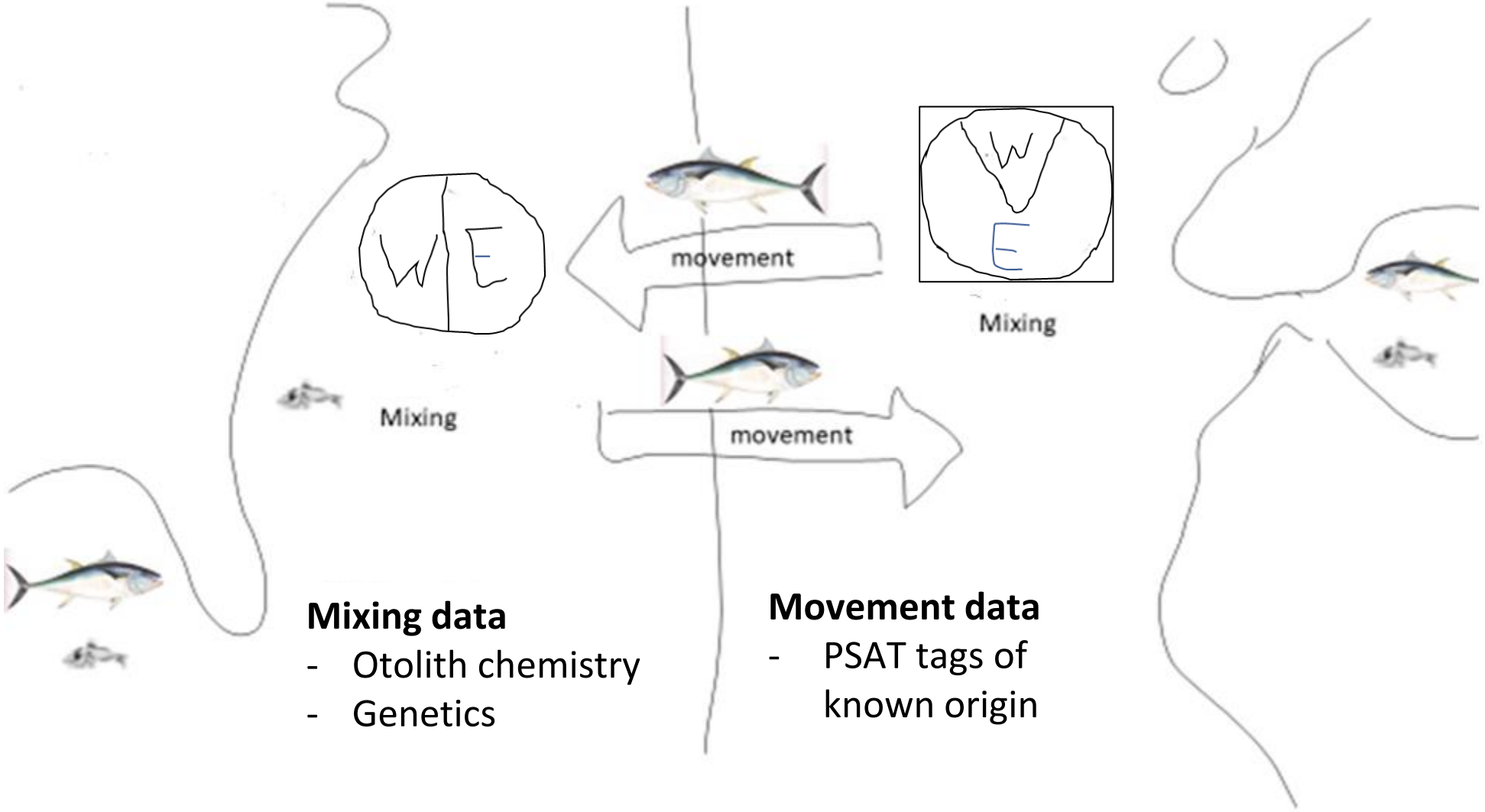
- Specifications
  - Time period (history) 1864-2019
  - 7-area model
  - 4 Quarters (Jan-Mar, Apr-Jun, Jul-Sept, and Oct-Dec)
  - Spawning occurs for both stocks in quarter 2
    - Mediterranean for Eastern stock
    - Gulf of Mexico & Western Atlantic for Western stock
  - Age structured (3 age groups)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

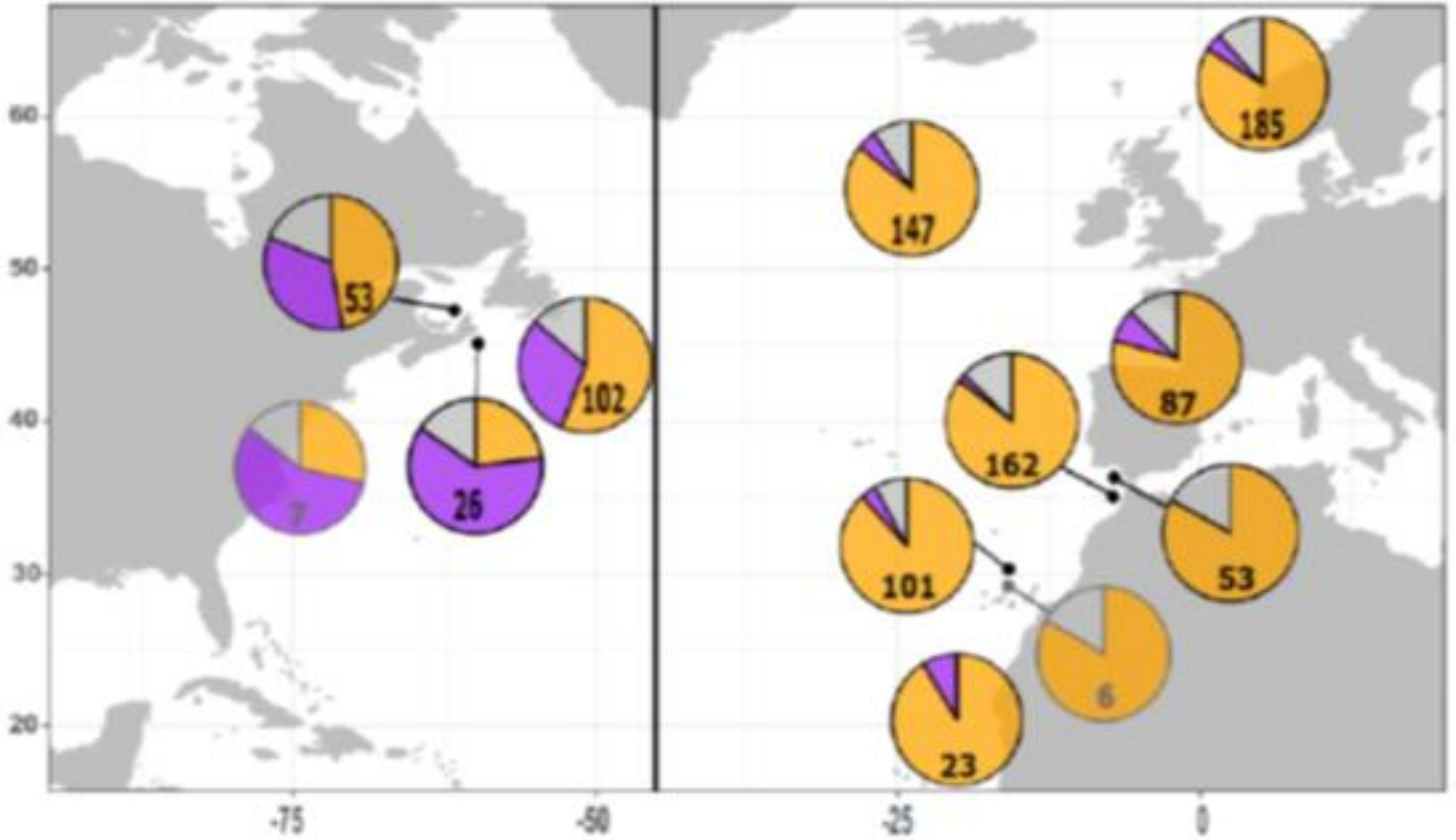
Movement data
- PSAT tags of known origin

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.

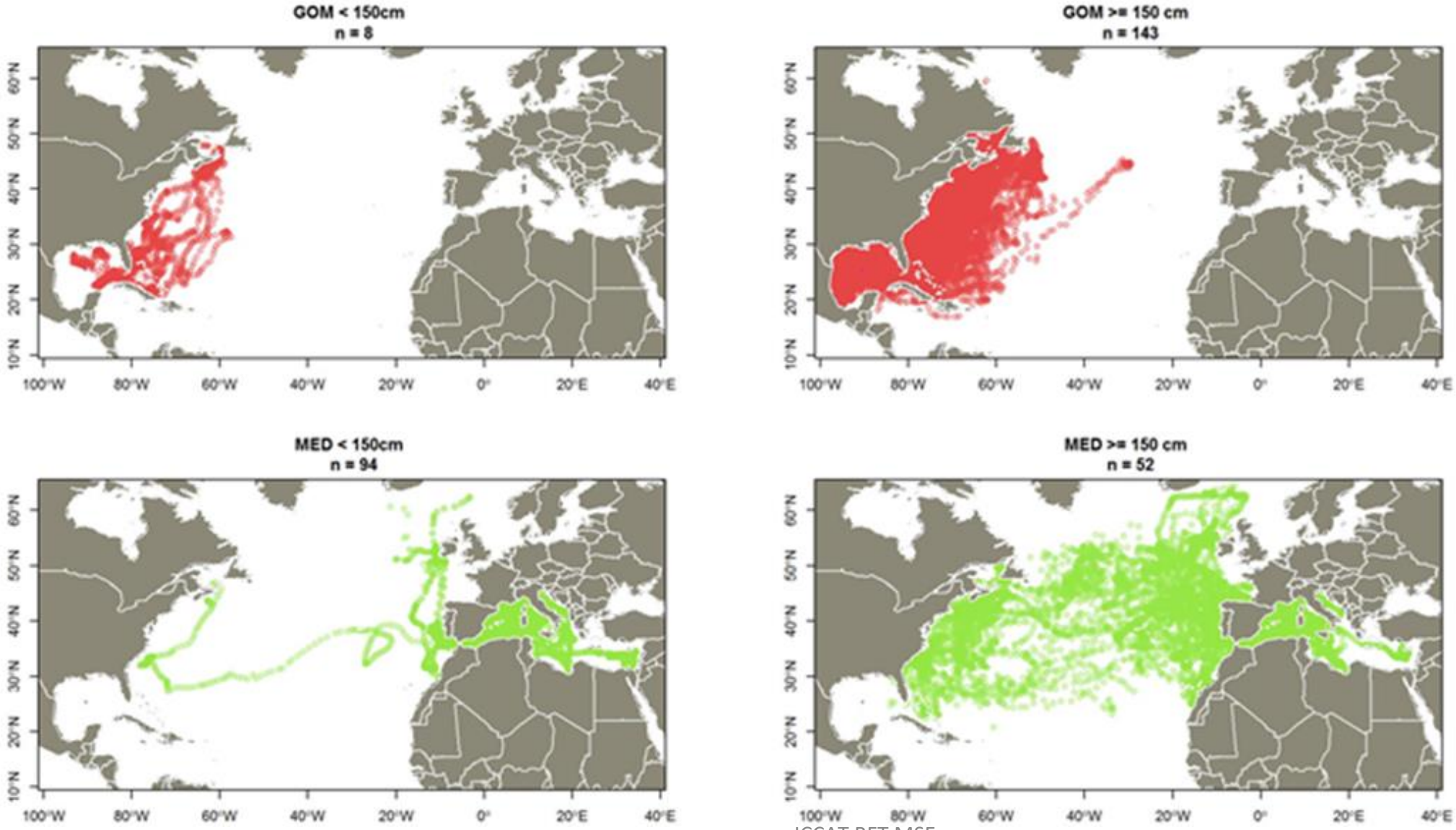
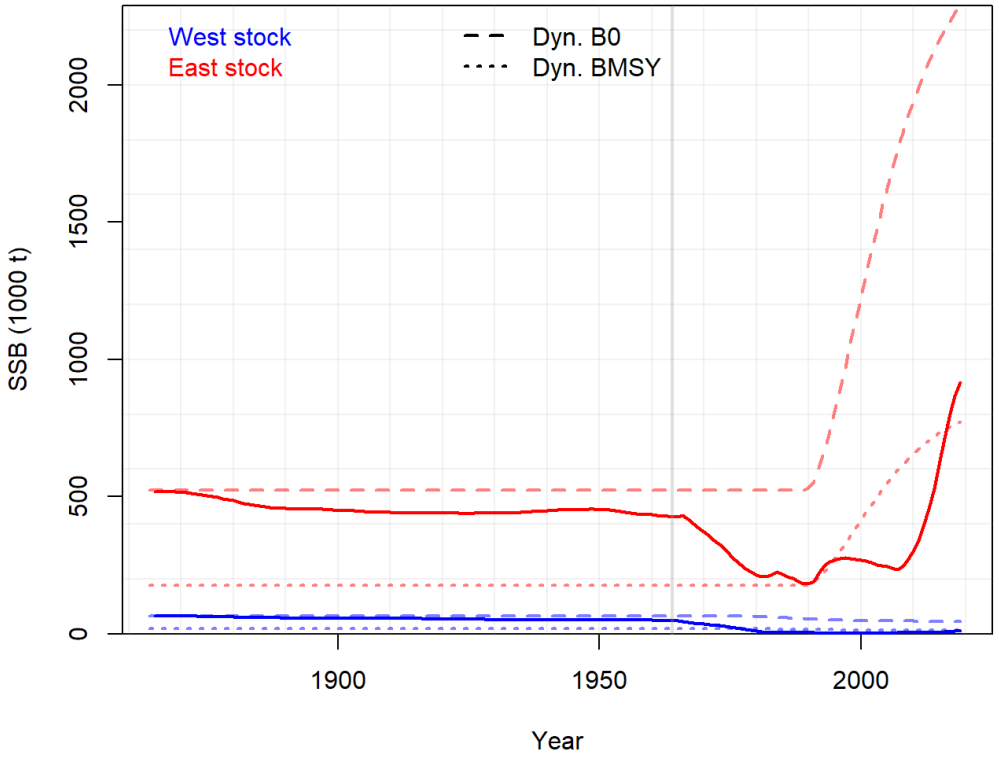


Figure courtesy of Ben Galuardi (NOAA-Fisheries)

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 (i.e., 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 provides a realistic yardstick for evaluating management performance.



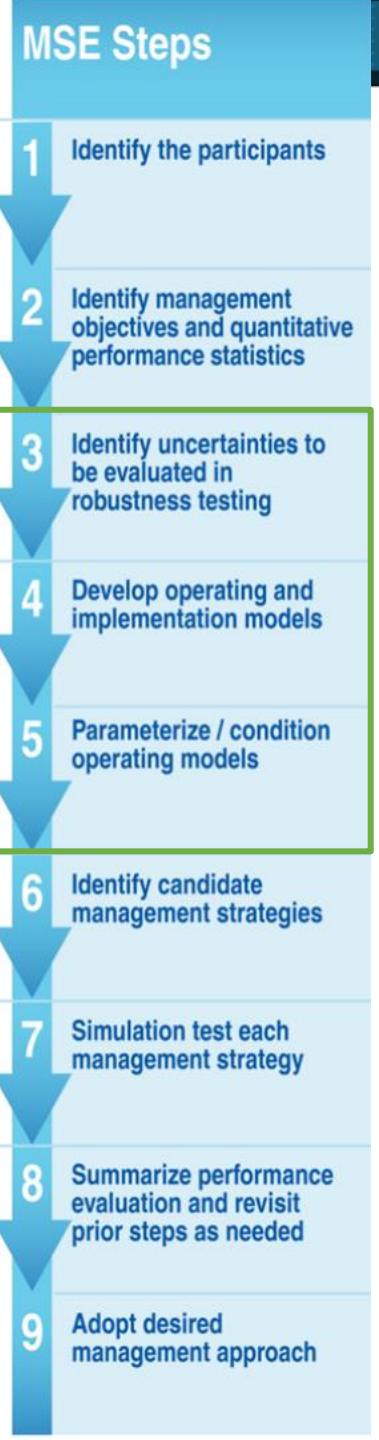
This is for OM1 which has a regime shift where the Eastern stock recruitment shifts from medium to high and the Western stock recruitment shifts from high to low.

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

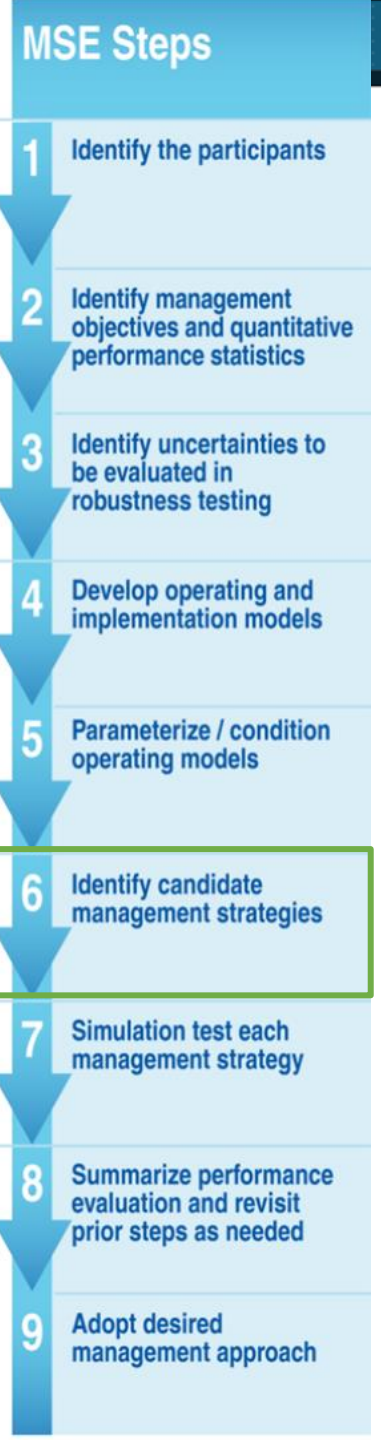
Solid lines are total biomass.

48 Operating models: 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 directly in TAC formula
- 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.
- More similar to stock assessment advice framework.

5. Overview of MP implementation

Many CMPs have the following basic constant fishing mortality form to provide TAC for east (or west) area:

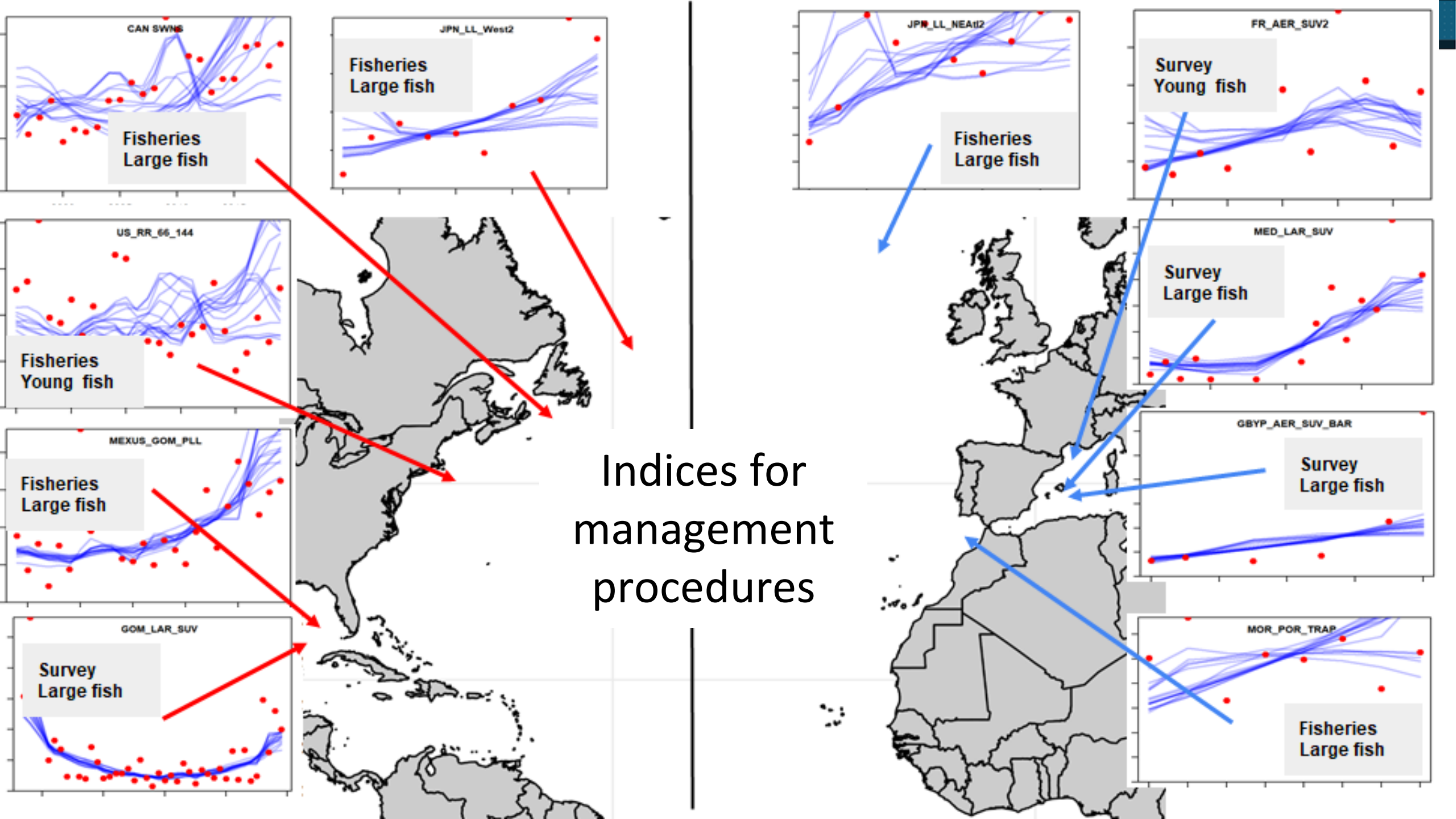
TAC = constant x average index for the area

where the index can be one or some weighted average over multiple indices for recent (usually 3 years).

Thus, if the indices increase, so does the TAC in proportion, and similarly if they decrease.

The size chosen for the constant determines whether the CMP is more aggressive (higher values) or more precautionary (lower values).

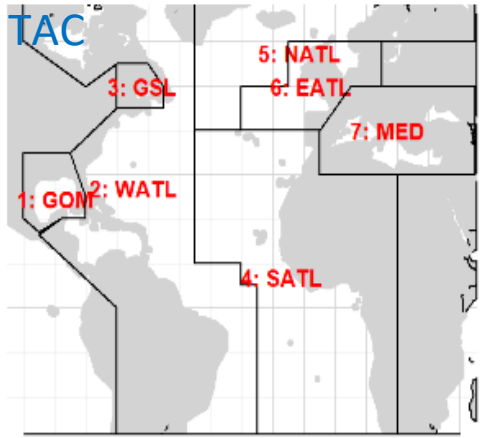
Naturally, different CMPs have different variations around that basic form, such as limitations on the extent to which the TAC can change from one year to the next, different built-in safety.


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

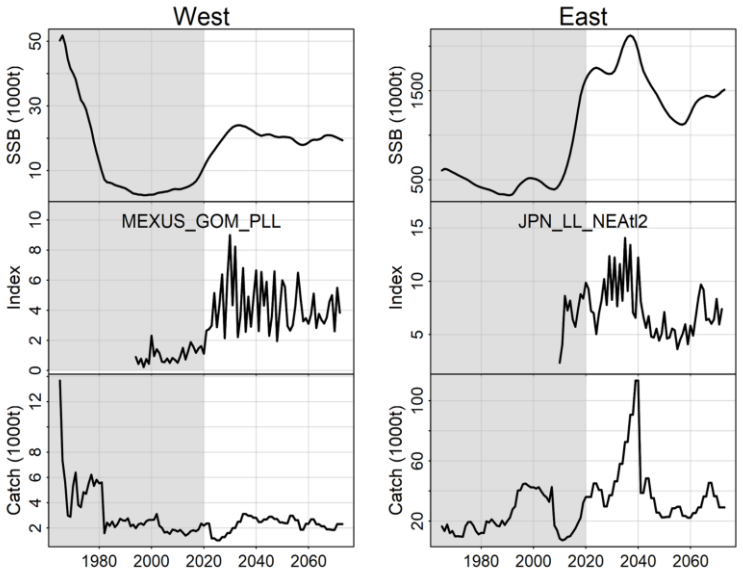
How a BFT Management Procedure would work

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**

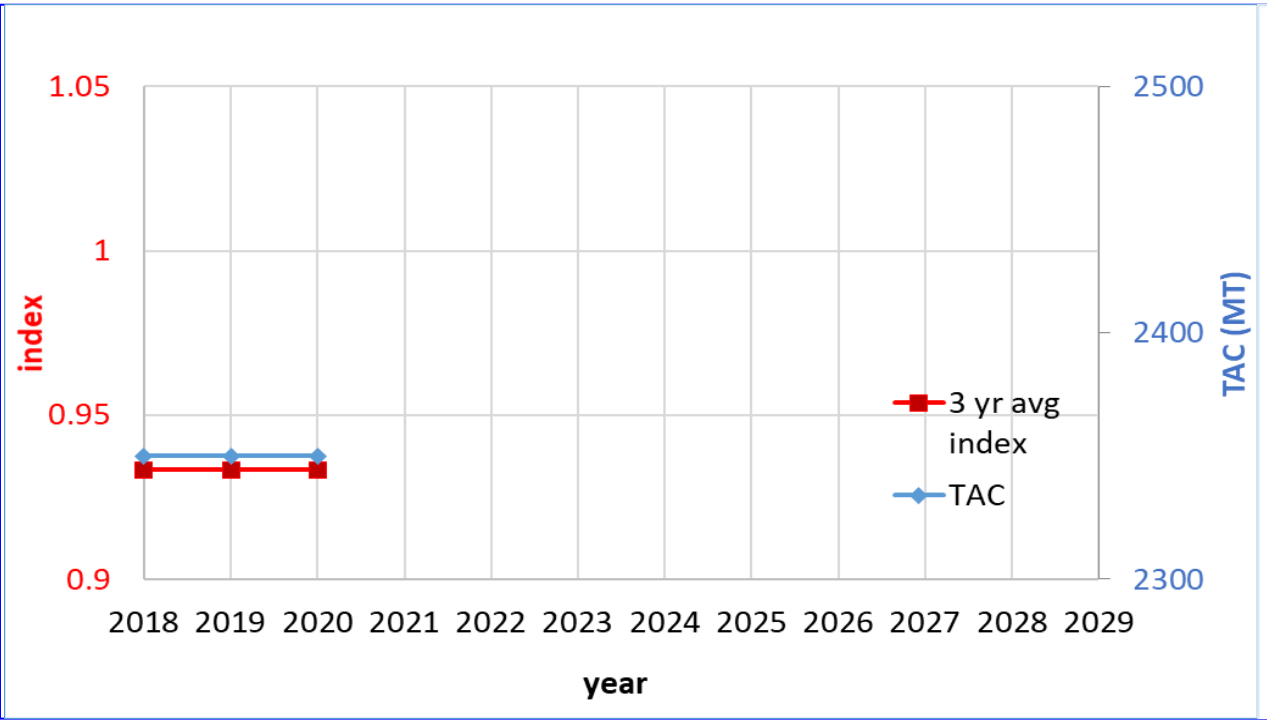
Statistics apply to Area to **Yield** & **Stability** of catch

- 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

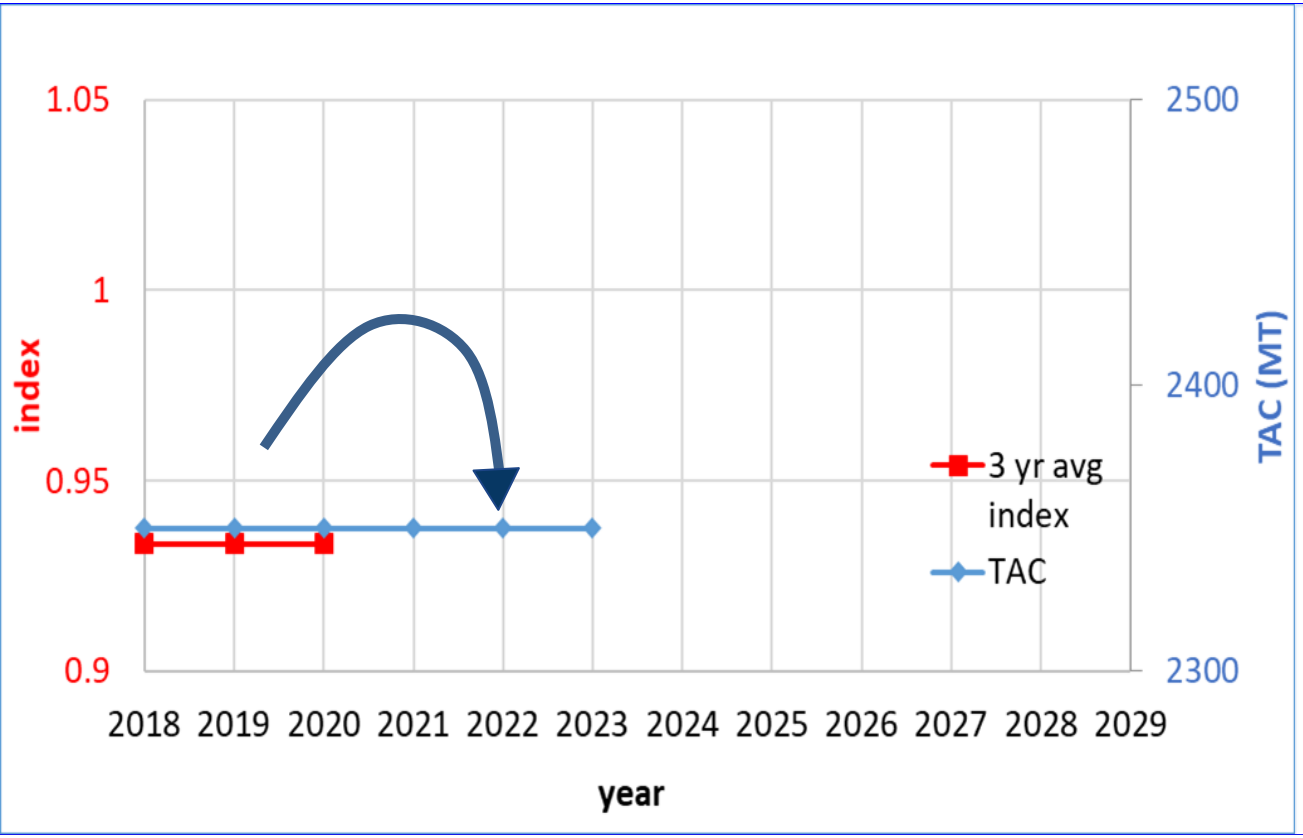


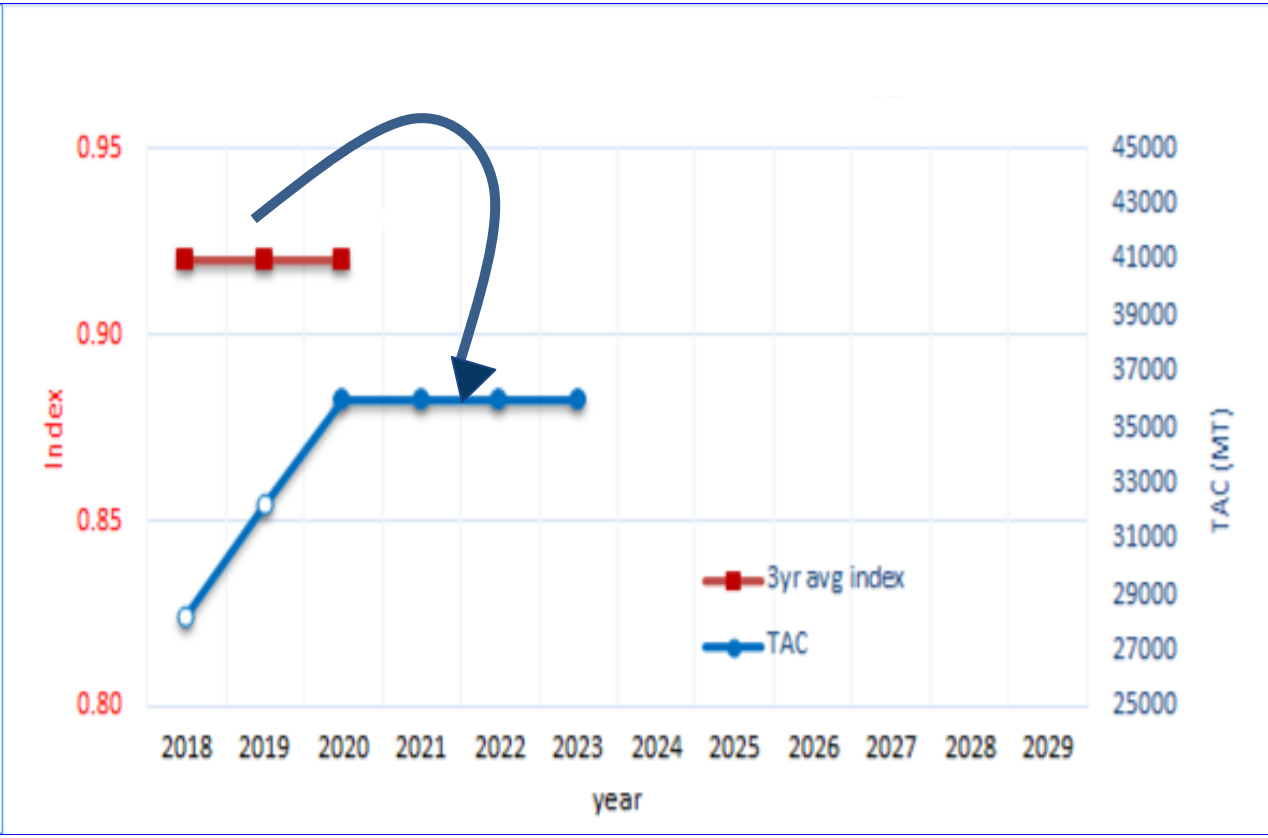
- Empirical management procedure based on index
- SCRS collects data, applies MP
- Commission sets TAC based upon MP advice
- TAC remains for *X* years

Conceptual vision for a Bluefin Management Procedure

WEST **EAST**

index constant = maintain TAC

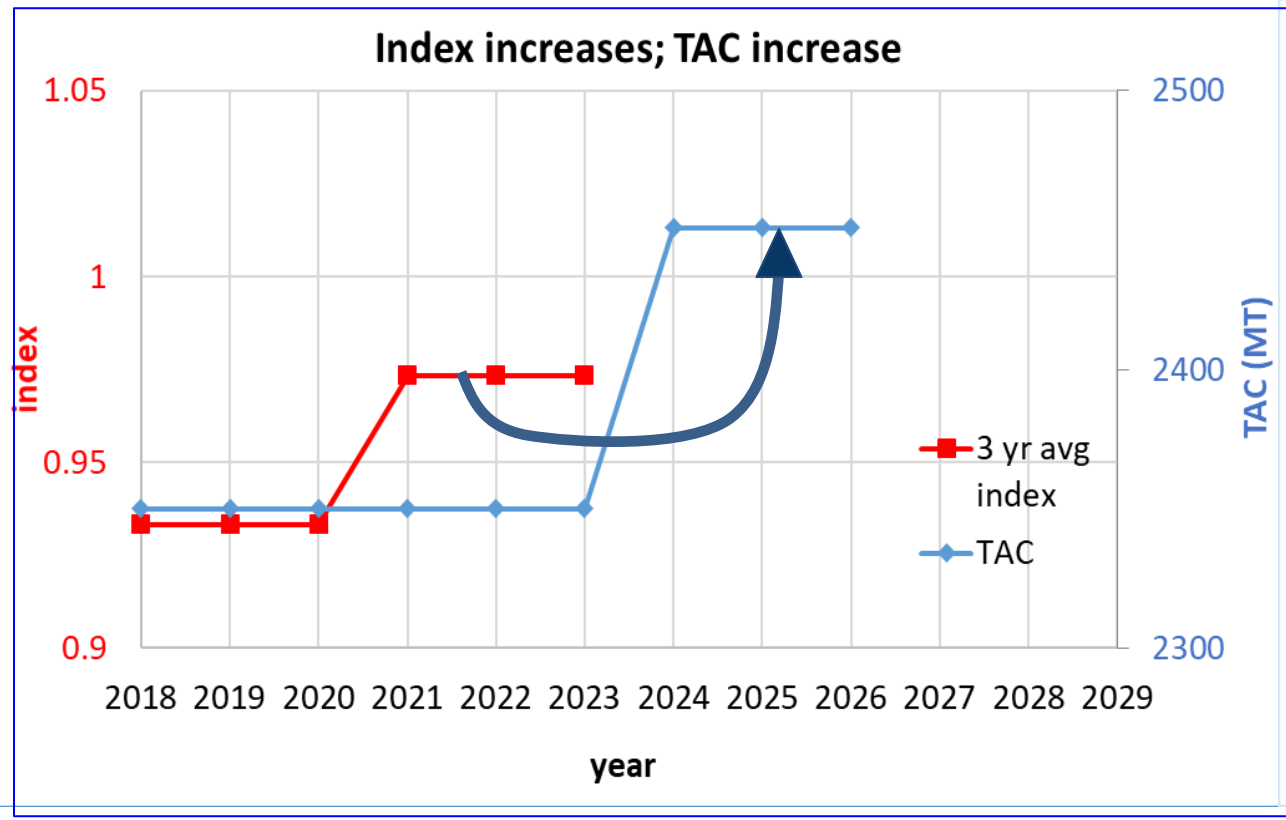




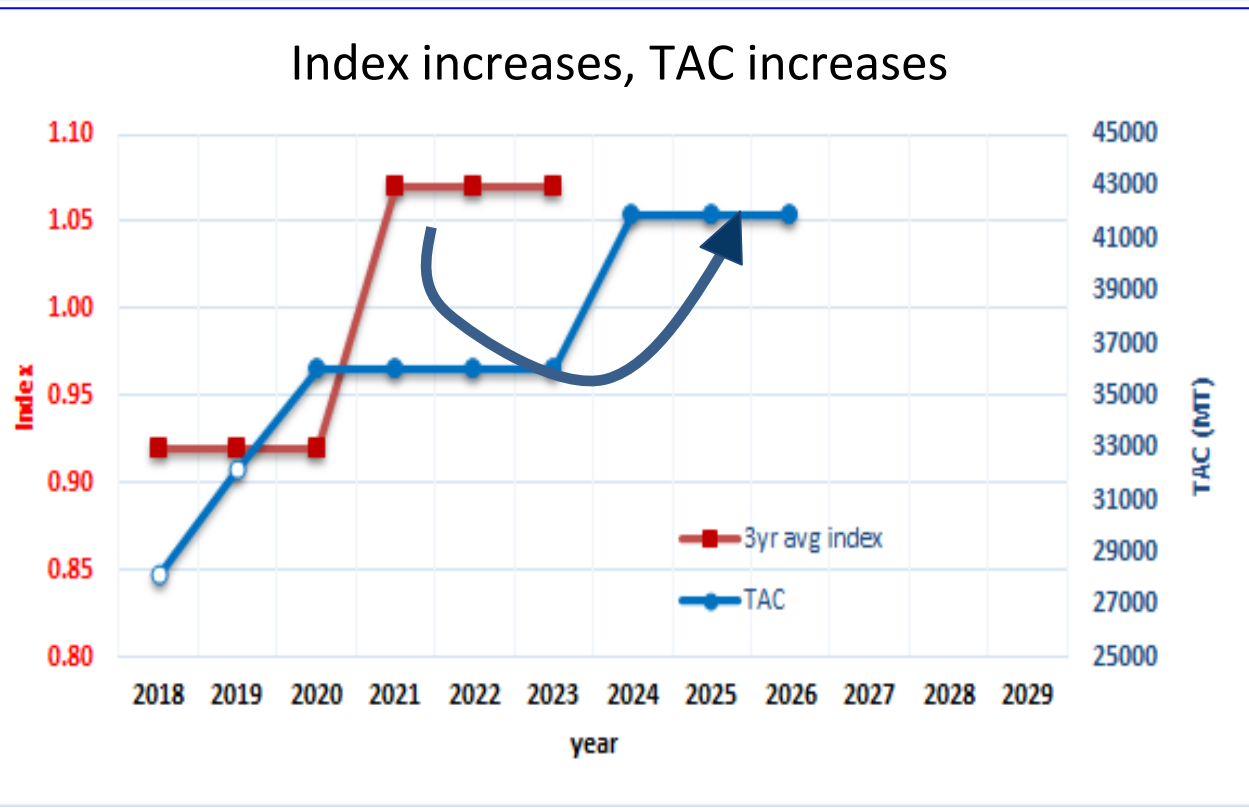
* Note that this is simply for illustration purposes and does not imply what would actually happen in the future.

Conceptual vision for a Bluefin Management Procedure

WEST



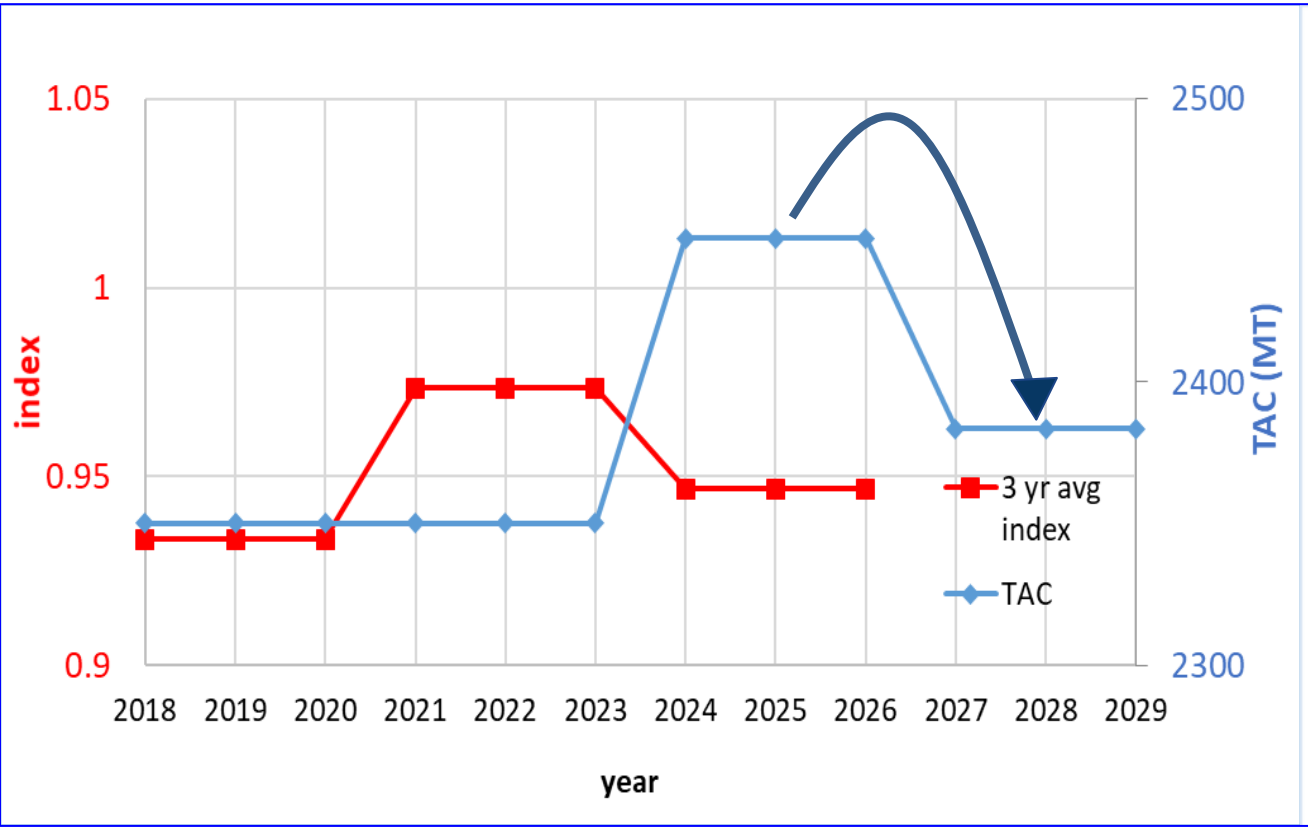
EAST

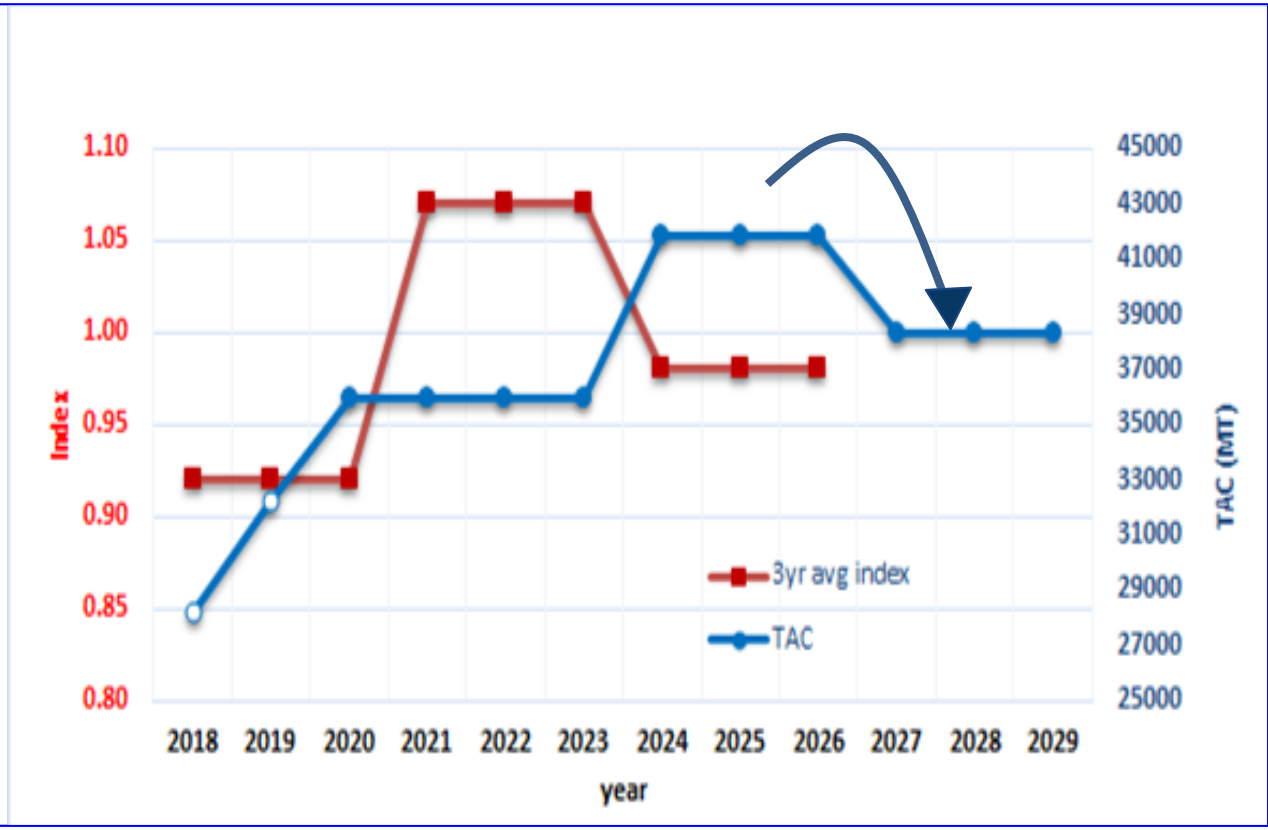


Conceptual vision for a Bluefin Management Procedure

WEST **EAST**

index decreases, TAC decreases

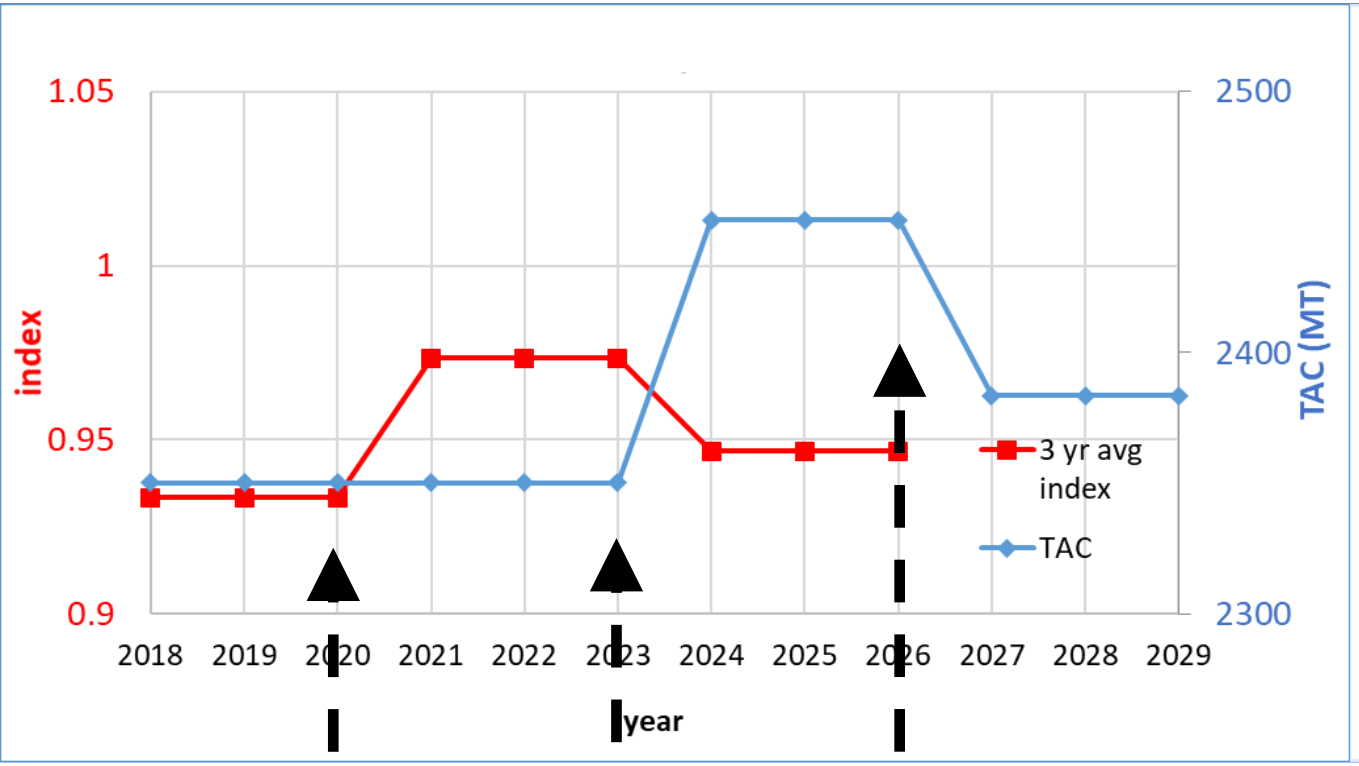


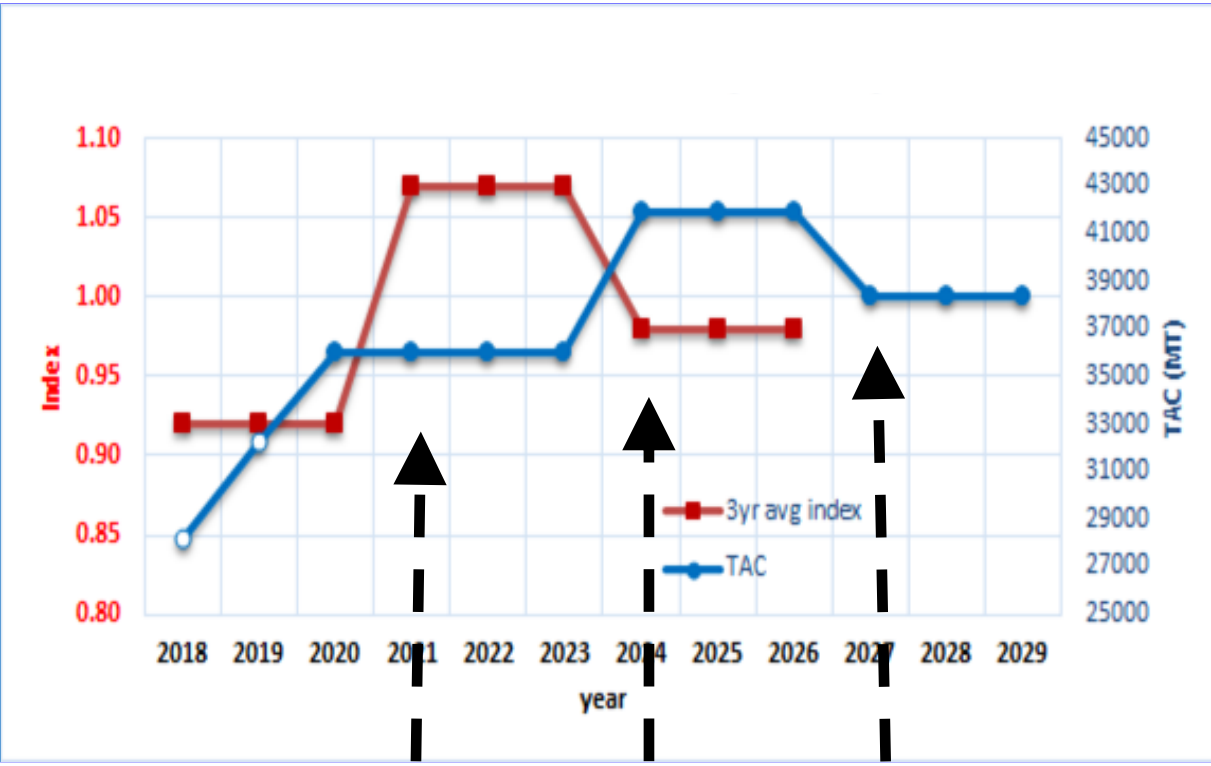


Conceptual vision for a Bluefin Management Procedure

WEST **EAST**

TAC set every three years



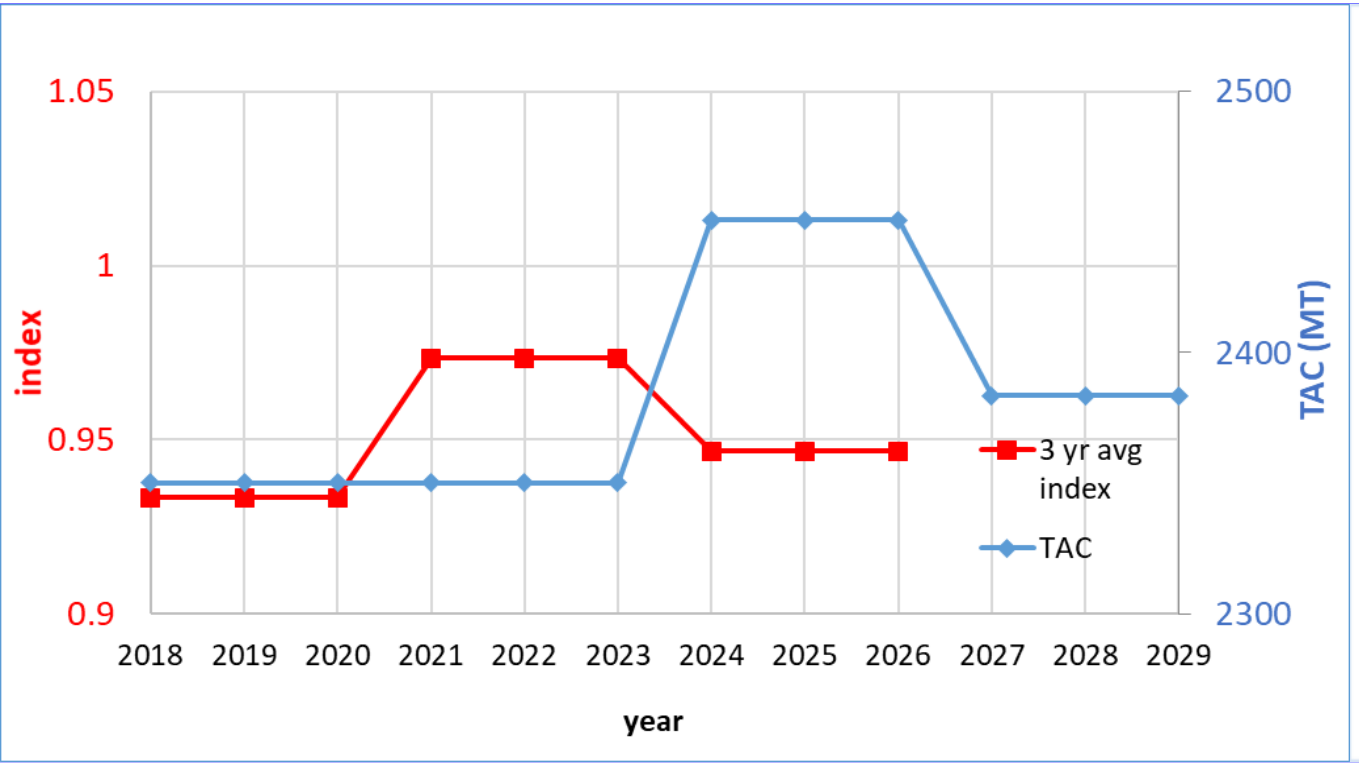


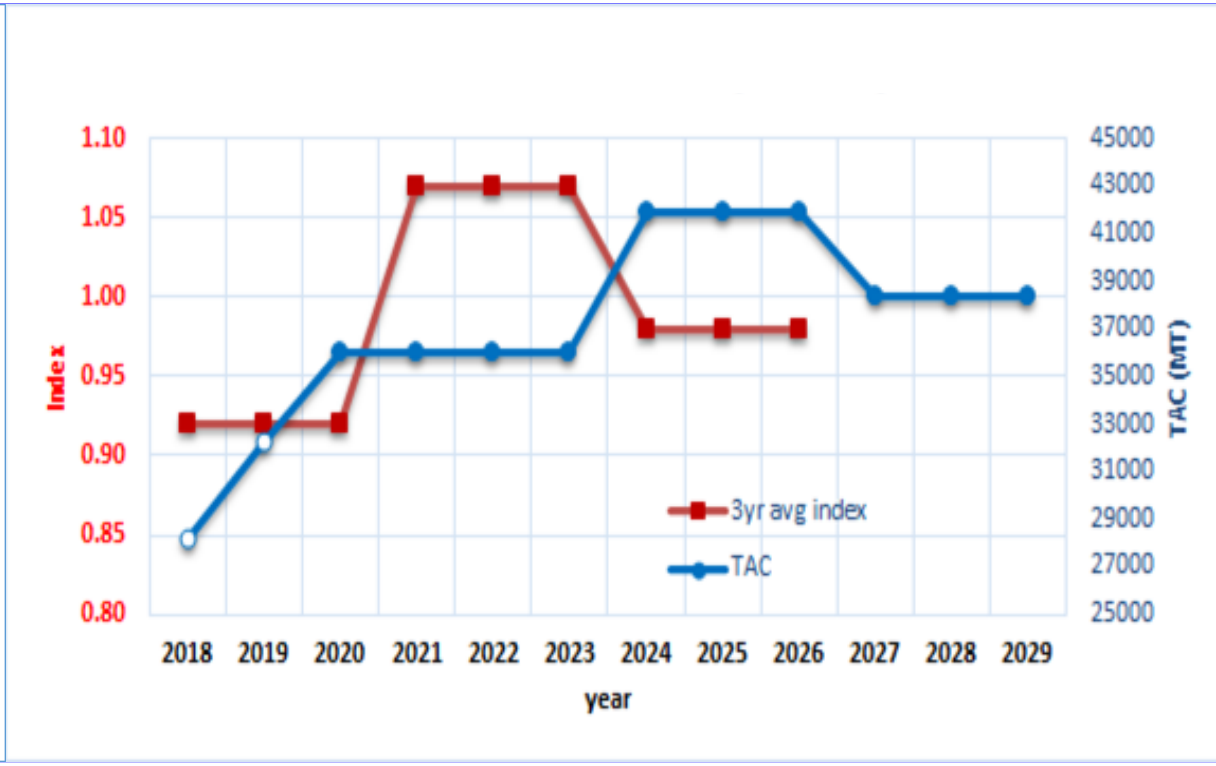
At pre-specified intervals, Commission adopts a new TAC, based on pre-agreed **Management Procedure.**

Conceptual vision for a Bluefin Management Procedure

WEST **EAST**

TAC set every three years

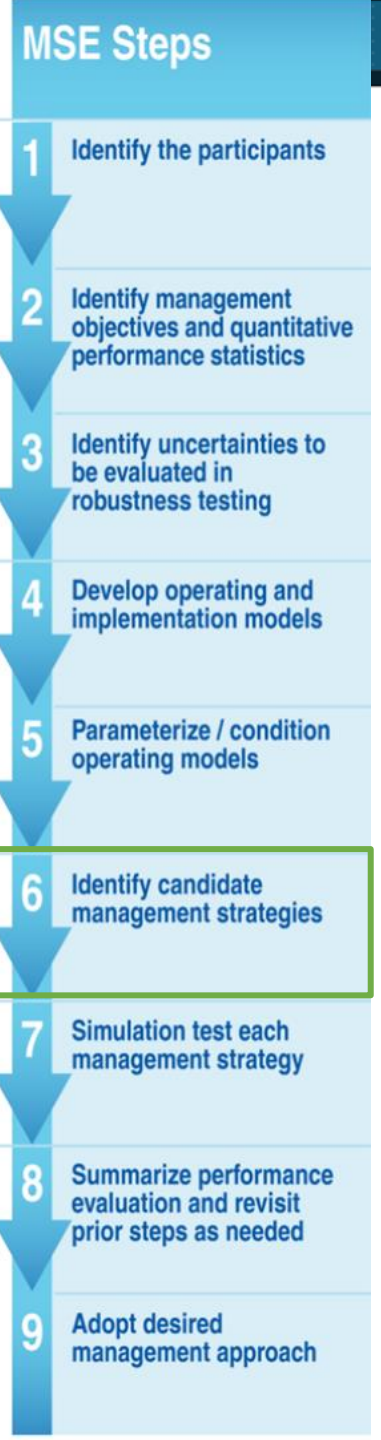




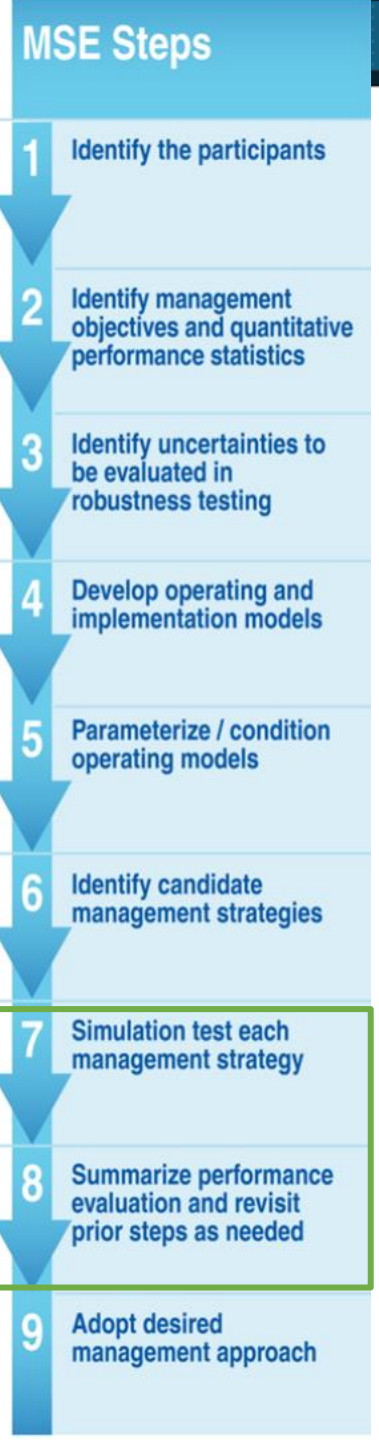
- Adopted MP would have been simulation tested
- To have high probability of achieving **Operational Management Objectives**
- Process has inherent stability, uses terminal year TAC, % change usually limited
- Routine, but less frequent stock assessments would continue

Candidate Management Procedures (9)

CMP	Indices used		Formulae for calculating TACs	References
	EAST	WEST		
FZ	FR AER SUV2 JPN LL NEAtl2 W-MED LAR SUV	US RR 66-144, CAN SWNS RR 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 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 W-MED LAR SUV MOR POR TRAP JPN LL NEAtl2	GOM LAR SUV US RR 66-144 US-MEX GOM PLL JPN LL West2 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 SCRS/2021/152
EA	FR AER SUV2 W-MED LAR SUV MOR POR TRAP JPN LL NEAtl2	GOM LAR SUV JPN LL West2 US RR 66-144 US-MEX GOM PLL	Adjust TAC based on ratio of current and target abundance index.	SCRS/2021/032 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 an 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 JPN LL NEAtl2 W-MED LAR SUV GBYP AER SUV BAR	US RR 66-144	TAC is adjusted based on F/F_{MSY} and B/B_{MSY}. (model-based).	SCRS/2020/150 SCRS/2020/165
TN	JPN LL NEAtl2	US RR 66-144 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 SCRS/2021/041



Management procedure questions



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

7. Illustrating the trade-off space and acceptable ranges in trade-offs

i. Trade-offs represent the decision space
ii. Yield vs. biomass
iii. Other trade-offs, including yield stability vs. average yield

Initial results: Tradeoff between stock status and yield

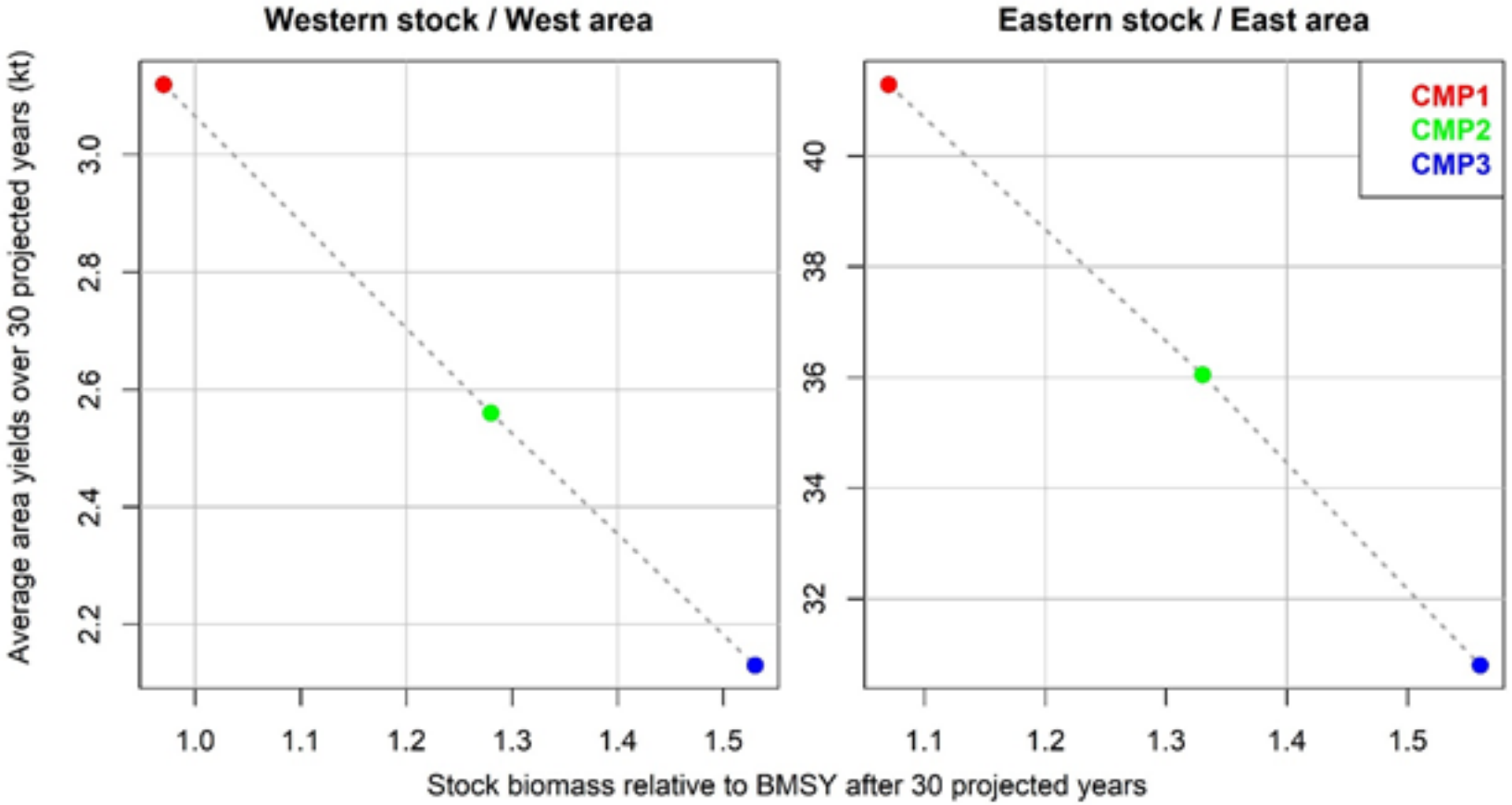
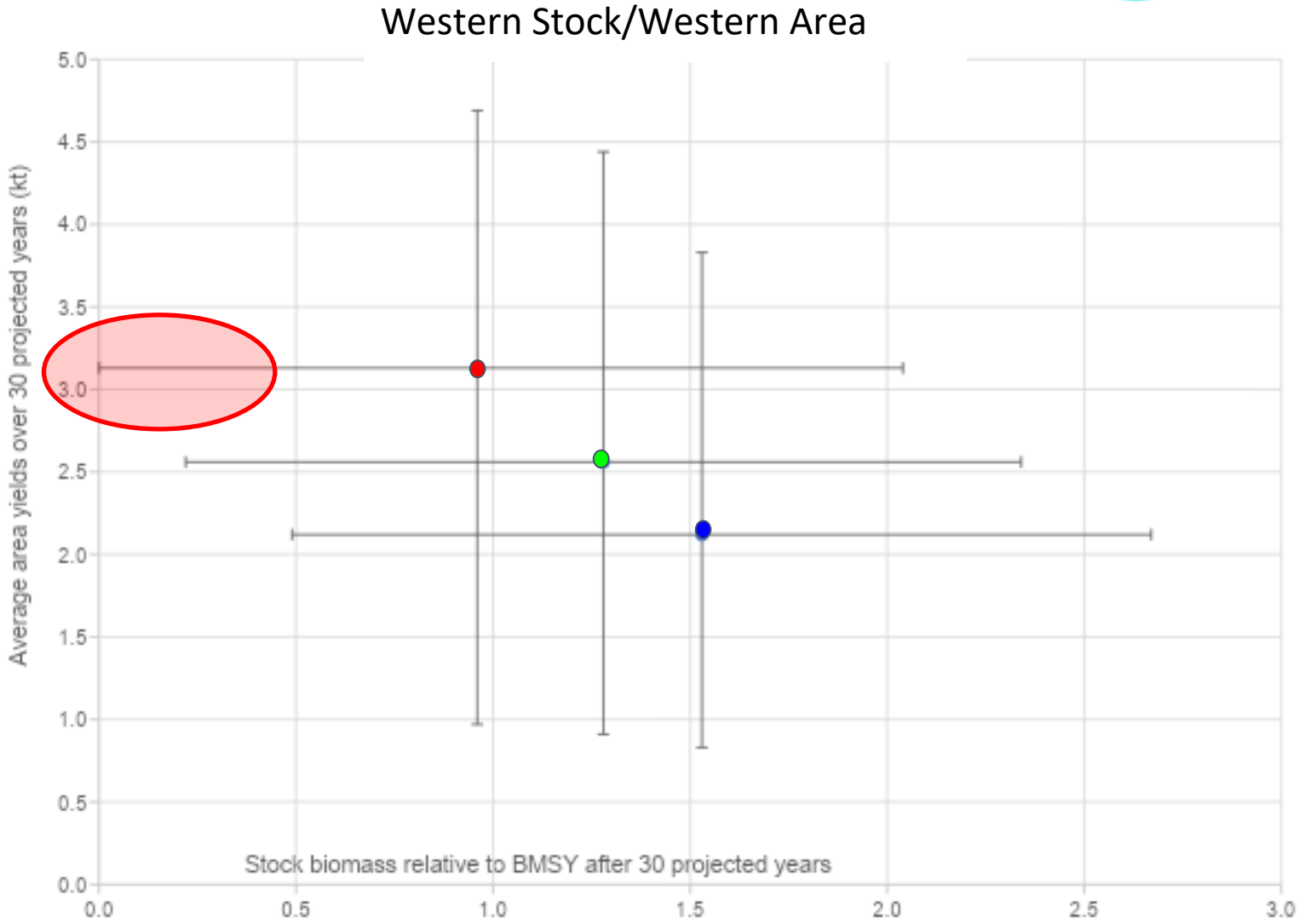


Figure 1. An example of the primary trade-off between yields (what is taken by fishing over 30 years, expressed as an annual average) and stock biomass (what remains in the resource after those 30 years) for three CMPs (CMP1 – red, CMP2 – green, CMP3 – blue). The left panel features western *stock* biomass (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.

Why we would not aim for BR30 (B/Bmsy) = 1

- Essential to look at tails of distribution

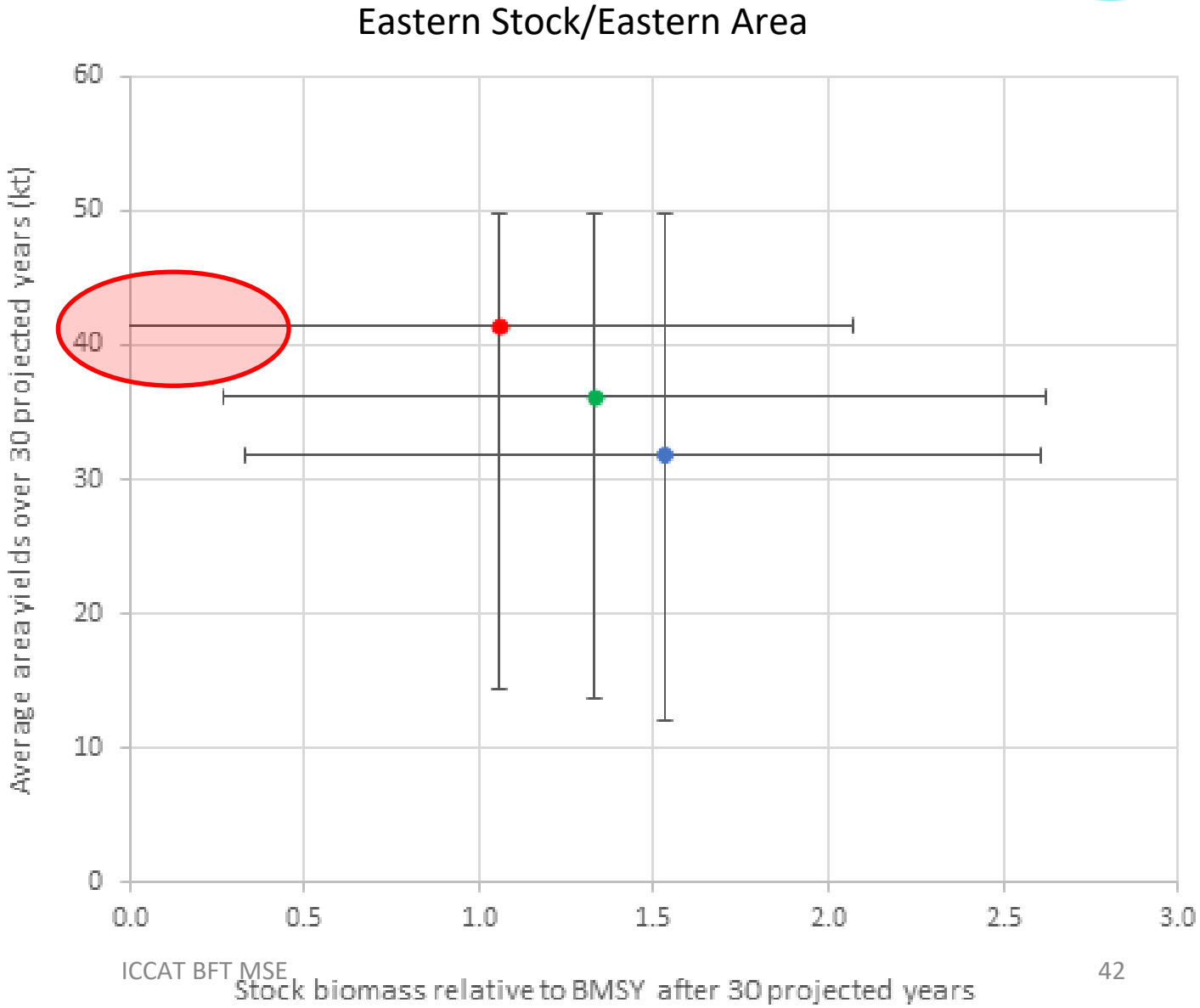
Figure 1: Western Area Yields (what is taken by fishing over 30 years, expressed as annual average) vs stock biomass (what remains in the resource after those 30 years) for three CMPs (CMP1 – red, CMP2 – green, CMP3 – blue), with three different median Br30 tunings. The 90% error bars are also shown.



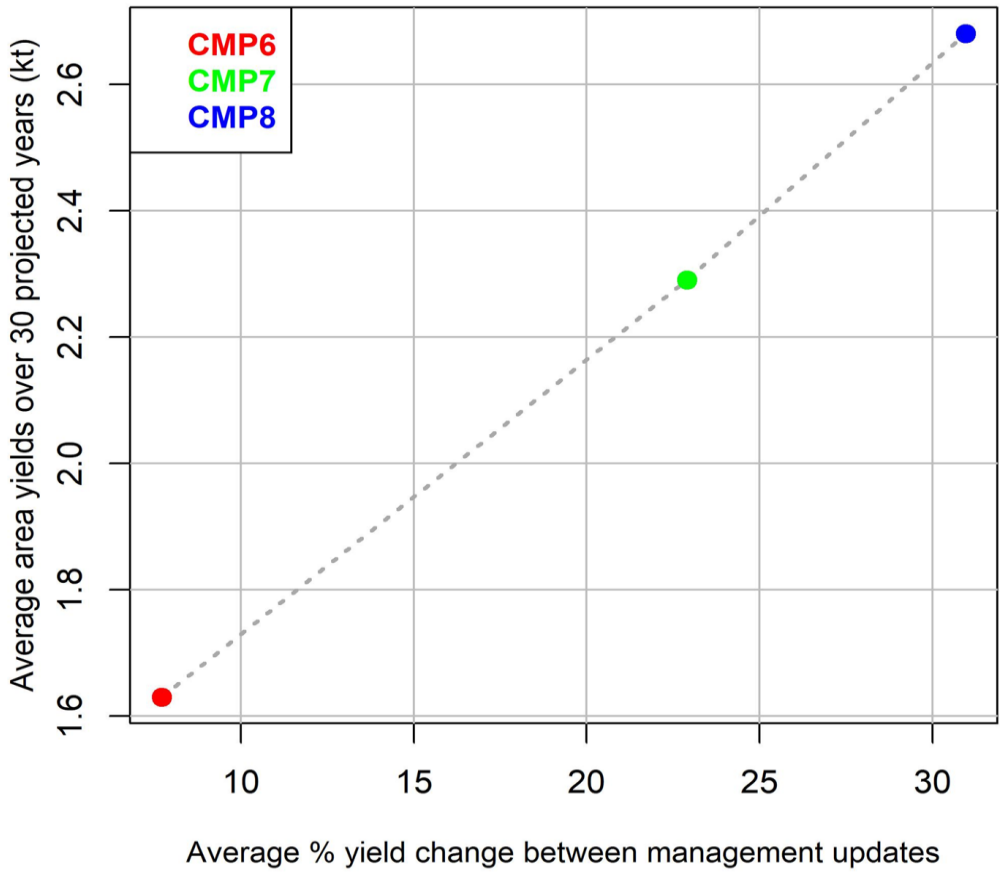
Why we would not aim for BR30 (B/Bmsy) = 1

- Essential to look at tails of distribution

Figure 1: Eastern Area Yields (what is taken by fishing over 30 years, expressed as annual average) vs stock biomass (what remains in the resource after those 30 years) for three CMPs (CMP1 – red, CMP2 – green, CMP3 – blue), with three different median Br30 tunings. The 90% error bars are also shown.



Initial results: Tradeoff between yield and variability in yield



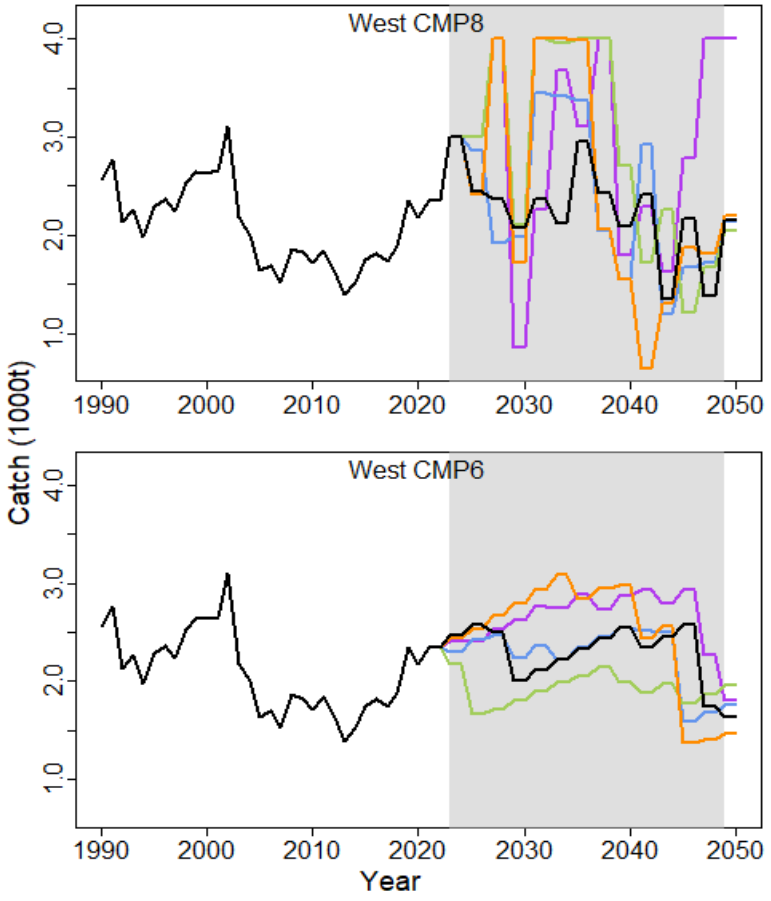


Figure 2. Performance trade-off between West area yields and yield variability. The left panel shows the tradeoff on average over the 30-year projection period across three CMPs (CMP6 – red, CMP7 – green, CMP8 – blue) with comparable biomass performance. Higher catches of CMP8 (upper right blue point) 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.

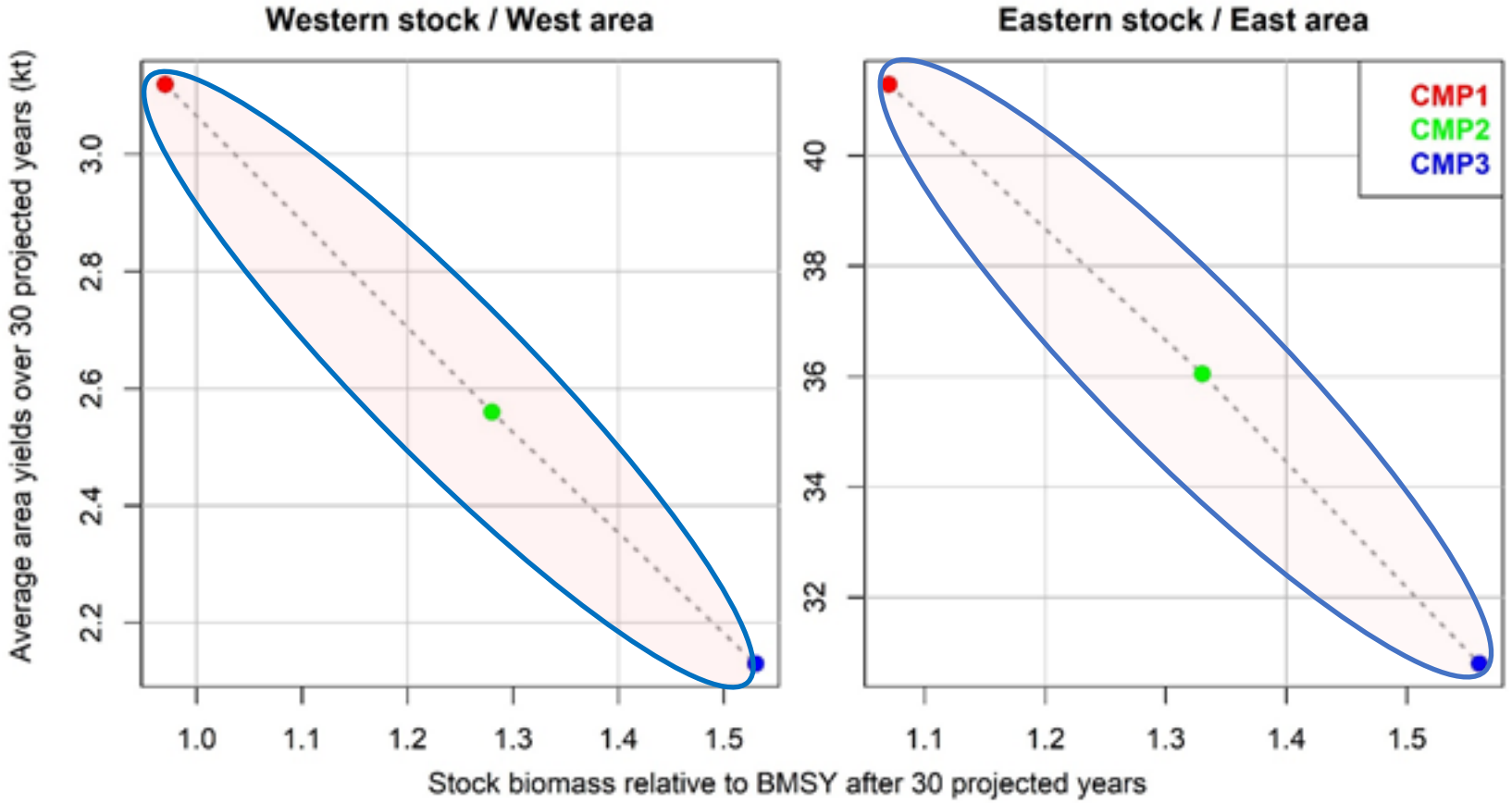
General process for narrowing down CMPs

- Eliminate clearly failing CMPs (e.g. ones that crash OMs).
- SCRS will rank CMPs across performance statistics (yield, status, safety and stability).
- Once performance has been considered, then other ‘satisficing’ criteria will be evaluated, e.g. are the indices used likely to be maintained, are there intangible concerns with certain indices, etc.
- Any candidate Management Procedure (CMP) will include at least one “control parameter” whose value determines how heavy or light the fishing pressure on the stock will be.
- Ultimate decision by the Commission will likely be from a range of CMPs from heavy to light fishing pressure.

8. Decision points on operational management objectives & performance statistics

1. The default is not to place caps on maximum TAC. But, if performance requires use of a cap on TAC, what are your thoughts on caps?
2. If we have to build in a constraint on annual variation in TAC, is 20% a reasonable starting point?
3. Currently we do not have a fishing mortality performance statistic. What are your thoughts on this?

4. Thoughts on status and yield tradeoff space, do we need to explore wider ranges?



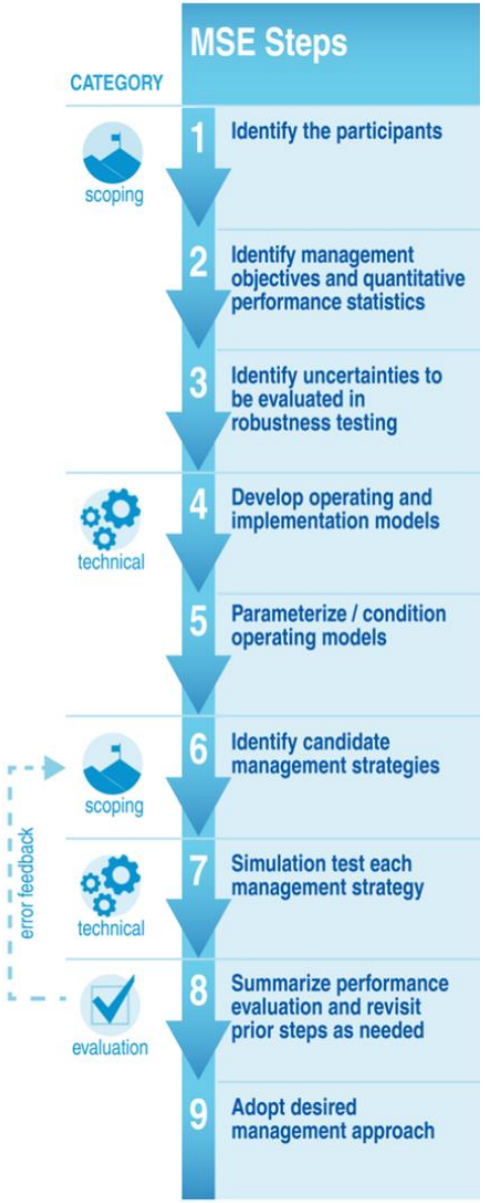
The ellipse is the primary decision space where most CMPs will fall.

Br30<1 involves high risk whereas Br30>1.5 reduces yield substantially.

Ambassador meetings feedback

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

9. Next Steps - 2022



ICCAT Commission & SCRS workplan toward 2022 adoption

November 2021 Panel 2 MSE meeting & Commission meeting

2022

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

March Commission Panel 2 meeting

April BFT WG intersessional

May/June Panel 2 meeting

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

May/June BFT MSE TT CMP Developers incorporate P2 advice

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

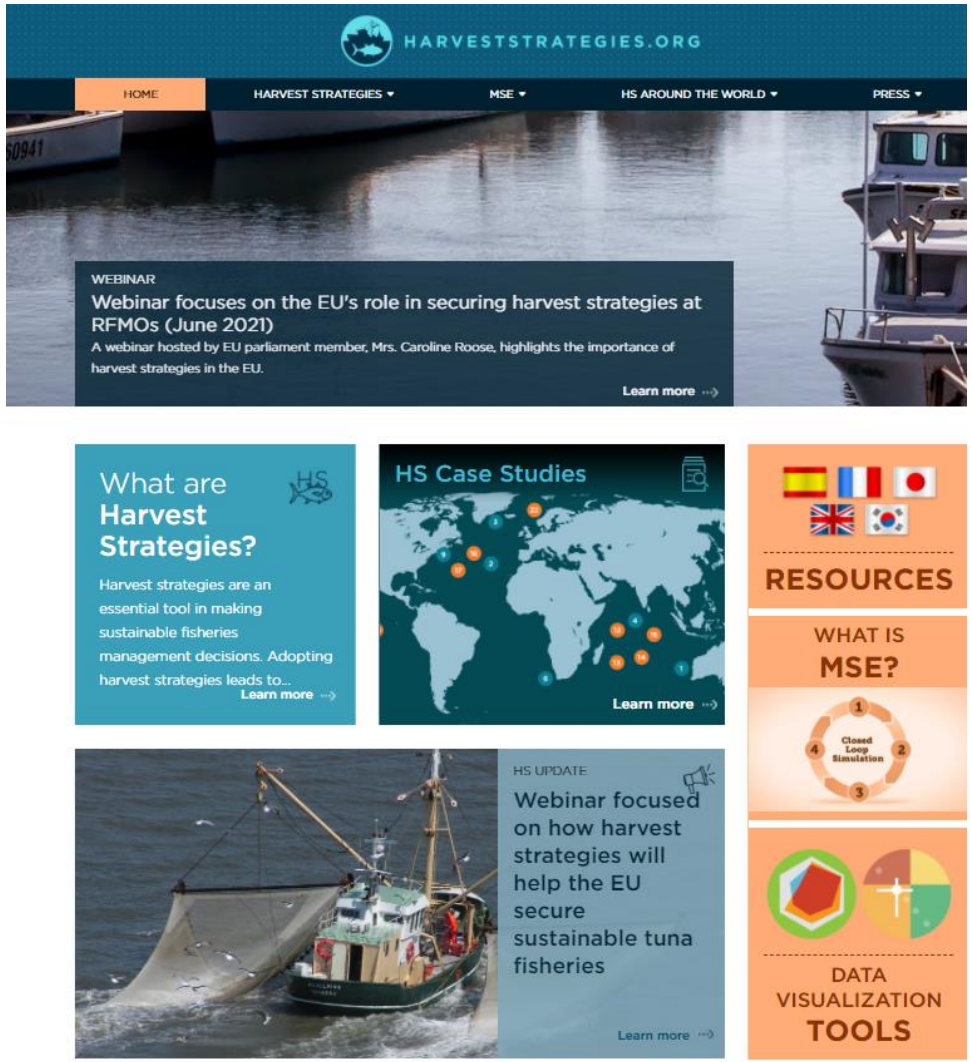
See detailed table: PA2_03_MSE_ENG

Key MSE documents

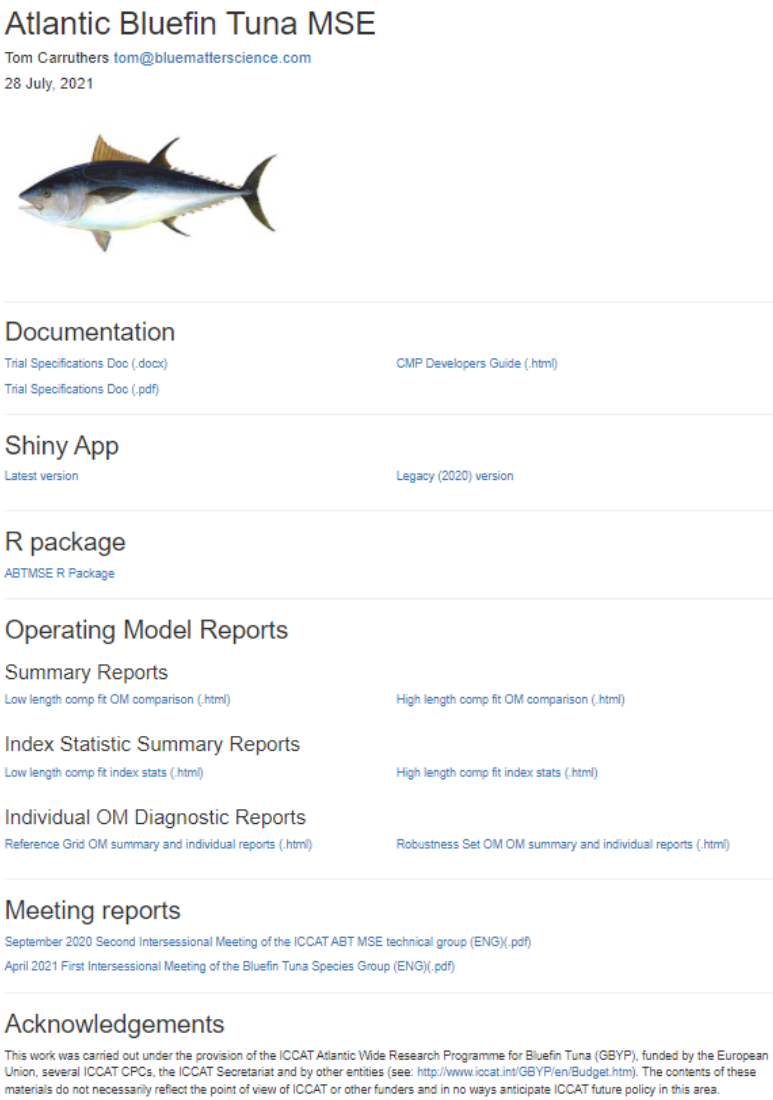
1. BFT MSE summary 4-page (BFT_MSE_02_2021)
2. BFT MSE summary 1-page (BFT_MSE_01_2021)

Other Resources

[Harveststrategies.org MSE outreach materials](#)
(multiple languages)



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



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.

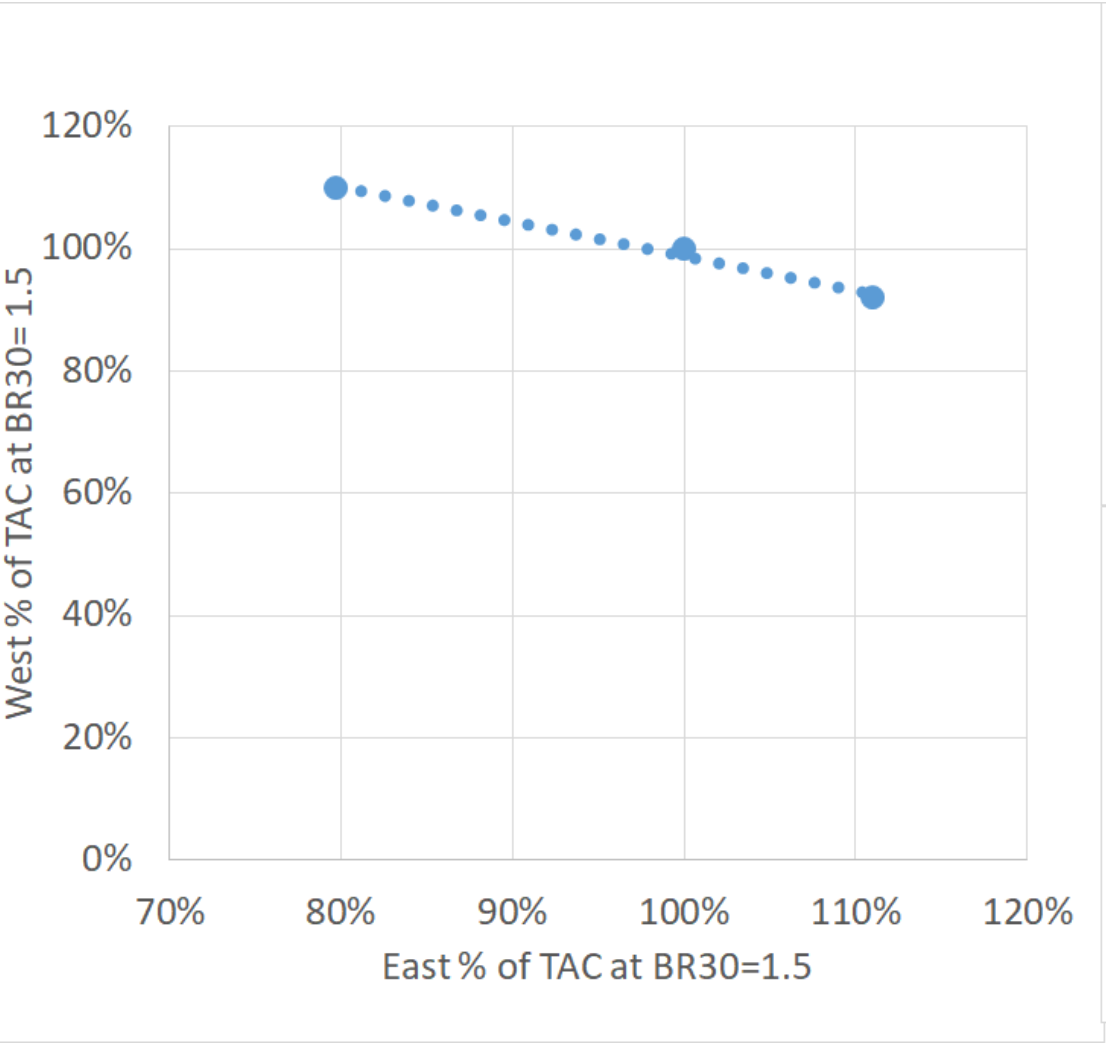
Operating model (OM): A model representing a plausible scenario for stock and fishery dynamics that is used to simulation test the management performance of CMPs. Multiple models will usually be considered to reflect the uncertainties about the dynamics of the resource and fishery, thereby testing the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

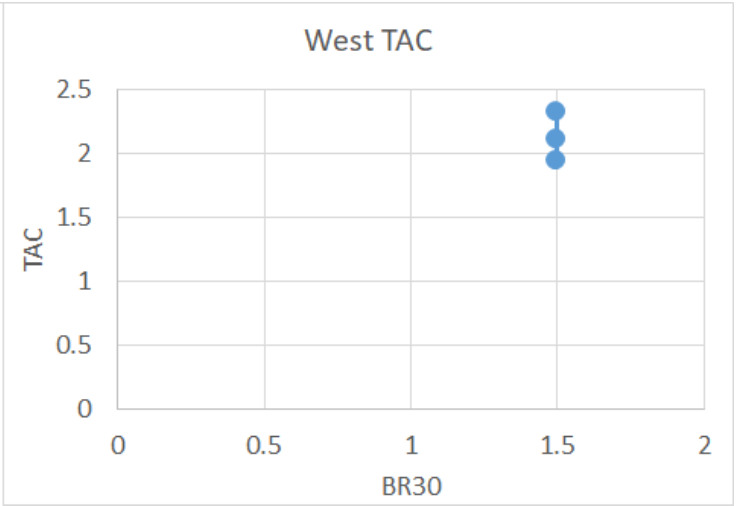
Performance statistic: A quantitative expression of a management objective used to evaluate how well an objective is being achieved by determining the proximity of the current value of the statistic to the objective. Also known as a performance metric or performance indicator.

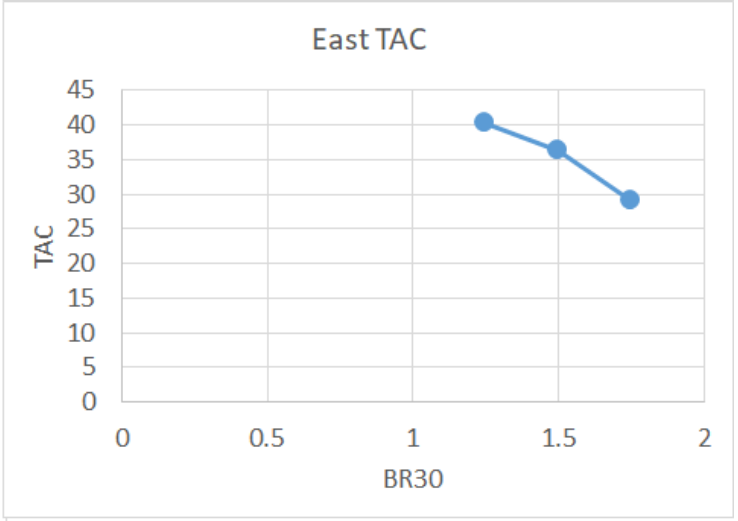
Reference Grid: The operating models that represent the most important uncertainties in stock and fishing dynamics, which are used as the principal basis for evaluating CMP performance. The reference operating models are specified according to factors (e.g., natural mortality rate) that have multiple 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.

Robustness tests

Table 9.4. Robustness tests, including priority and OMs on which the test is to be conducted.

Priority	Robustness test description	Notes
1	**Western stock growth curve for eastern stock.**	West: 55% vs East: Growth 45% in plausibility weighting poll.
2	**Catchability Increases.** CPUE-based indices are subject to a 2% annual increase in catchability in the future.	Simple to do and a fundamental concern.
3	**Unreported overages.** Future catches in both the West and East areas are 20% larger than the TAC as a result of IUU fishing (not known and hence not accounted for by the CMP).	Important implications and simple to do.
4	**High western mixing.** The old mixing axis factor level 2: 20% western stock biomass in East area on average from 1965-2016.	Demoted from the reference grid, this provides a yardstick for evaluating whether robustness trials are 'consequential'. Important for setting scale, but not necessarily important for 'does it matter'.
5	'**Brazilian catches**'. Catches in the South Atlantic, including relatively high takes during the 1950s and 60s, are reallocated from the western stock to the eastern stock.	Important, but for practical purposes this should be developed after OMs priority 1-4 in order to prevent it absorbing disproportionate resources to get it working. If it proves to take inordinate amount of time, then suspend work on this to then move on to others in the list.
6	**Time varying mixing.** Eastern stock mixing alternates between 2.5%and 7.5% every three years.	Time consuming. Previously involved fitting two new operating models with 10% and 30% western mixing priors, but that dates back to before the 20% western mixing scenario was demonstrated to be inconsequential to CMP performance. Hence this has been changed to eastern time-varying mixing scenarios.
7	**Non-linear indices.** Hyperstability in OM fits to data is simulated in projection years for all indices.	Recondition the four operating models imposing a β parameter of 0.5 in the OM conditioning and maintain this in projections: $I = qB^{\beta}$ (needs change to M3 and M3 input files).
8	**Persistent change in mixing.** Eastern mixing increases from 2.5% to 7.5% after 10 years.	Was previously a change in western stock mixing before this was shown to be inconsequential to CMP performance. Hence this has been altered to a change in the eastern stock mixing as this will be influential.
9	Varying time of regime change in R3.	Currently this changes 10 years after management under the MP commences.
10	Intermediate parameter levels for M, growth, maturity, scale, regime shifts.	The mean of existing high and low scenarios.
11	Zero eastern stock mixing. No Eastern stock in the West area.	Zero eastern mixing, will require substantial further discussion regarding the interpretation. Apply only to the projections.
12	Upweight US RR 66 144	Upweight US RR 66 144 until appreciable changes are seen in in OM

Other robustness tests

Other Robustness trials

1) Probabilistic movement changes
2) Step-changes in catchability
3) Split Med Larval index

"Second round" issues

The following aspects of uncertainty are suggested to be postponed at this time for consideration rather in a "second round":

1) More than two stocks in some OMs
2) Model only a single stock in some OMs
3) Allow for CMPs that set TACs for the whole Atlantic (note that this will require specification of OM components that allocate such catches between West and East areas each year)
4) Use of CAL data in a CMP
5) TACs allocated on a spatially more complex basis than the traditional west and East+Med areas
6) CMP Changes in technical measures affecting selectivity
7) Changes in stock distributions in the future
8) Future changes in proportional allocation of TACs amongst fleets

B_{lim} (from https://www.iccat.int/Documents/Meetings/Docs/2021/REPORTS/2021_BFT2_ENG.pdf)

"The Group (SCRS) considered the request (SCRS/2021/154) to develop a biomass limit reference point (B_{lim}). The Group agreed that, for practical purposes and consistency with existing metrics in the MSE, the limit reference point should be in terms of SSB, that it should be dynamic as reference points are dynamic in the OMs. But given the complexity of the issue, and the fact that the value for B_{lim} is intimately linked to the probability of broaching e.g. lower B_{lim} values should be associated with lower probabilities of breaching, the Group recommended further consideration be taken. The Group noted that, additionally, it would be useful for the Developer to amend the package to calculate SSB_{lim} at 10 and 15% of SSB0 and to output probabilities for these two values."

Example ranking table

	AAVC	AvC10	AvC30	Br30	Mean_Rank
CMP1	0.794	49.5	49.743	0.374	2.88
CMP2	8.218	40.988	39.375	1.09	4
CMP3	25.825	41.712	33.584	1.267	5
CMP4	12.435	40.151	28.368	1.663	4.5
CMP5	30	61.363	40.831	1.415	2.75
CMP6	42.252	39.6	33.75	1.287	5.75
CMP7	8.753	49.5	36.138	1.327	3.12