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North Atlantic Swordfish MSE: Background, Structure, Preliminary Results and Key Decisions

Executive Summary

This document describes core concepts of the North Atlantic swordfish management strategy evaluation (MSE). The intention is to provide sufficient knowledge to facilitate decision-making and discussion among scientists, fishery managers and other stakeholders at the Panel 4 meeting on 30 June 2023 and continuing in the lead up to scheduled adoption of a management procedure (MP) in November 2023. This document summarizes the MSE structure, process, preliminary results, and key decisions for the June PA4 meeting.

Background

The SCRS Swordfish Species Group has been developing a management strategy evaluation (MSE) framework for North Atlantic swordfish (NSWO) for a decade (see **Appendix D** for key terminology). In 2009, ICCAT called for development of a limit reference point for swordfish (Rec. 09-02), and the Commission adopted $0.4*B_{MSY}$[1] as the interim limit reference point in 2013 (Rec. 13-02). Recommendation 13-02 also tasked the SCRS with development of a harvest control rule for N-SWO. In 2015, the Commission called for adoption of a management procedure (MP) based on an MSE for 8 priority stocks, including N-SWO (Rec. 15-07). In 2017, the SCRS developed an integrated, sized-structured stock assessment model for N-SWO on which a future MSE would be based. Funds were provided by the Commission in 2018 to develop the simulation framework, and following initial work by the SCRS, an MSE expert was contracted in 2019 to develop the N-SWO MSE. MSE development by the SCRS then began in earnest. The Commission adopted conceptual management objectives for N-SWO in 2019 (Res. 19-14) to help guide MSE development. In 2022, the SCRS carried out a new stock assessment in which the base case model was modified to incorporate discard mortality of undersized fish, and the MSE was updated with this new model. MSE development has continued in 2023, incorporating feedback provided by Panel 4 at its March 6th meeting. The MSE work is on track for ICCAT to adopt an MP in 2023, in accordance with the Commission's MSE workplan.

MSE overview

The N-SWO MSE is built using an open-source MSE software package called openMSE. The package can input information from Stock Synthesis stock assessments (the 2022 N-SWO stock assessment, in this case) to efficiently create – and then customize – an MSE framework for testing candidate management procedures (CMPs), including the approximately 100 CMPs that come preloaded in openMSE.

Indices of abundance

Data from 6 different longline indices and a harpoon index were used in the stock assessment and are used to condition the MSE. A combined index that incorporates raw data from seven CPCs is being used as the primary index for CMP development, however, other indices are also being considered. The MSE's historical period is from 1950 through to 2020, and projections cover the subsequent 33 years.

Operating Models

Each operating model (OM) in the MSE represents a plausible scenario/a potential truth for the dynamics of the stock and fishery. The N-SWO MSE includes nine main operating models (i.e., the "reference set or grid of OMs") based on two major sources of uncertainty:

[1] Spawning stock biomass (SSB; biomass of mature females), is used in this MSE.

1. Stock productivity: Steepness of the relationship between stock size and recruitment potential is one of the most important and uncertain inputs into stock assessments. Practically, this is often thought of as a measure of the stock's ability to rebuild biomass when depleted to a low level (3 options);

2. Natural mortality: the rate at which individuals die of natural causes (3 options).

The nine OMs allow for all combinations of these options (3x3=9). All OMs are considered to be equally plausible, so they are weighted equally. The three steepness values were updated in May 2023 in response to a Panel 4 request, and the new reference set has been reconditioned.

There are also nine sets of robustness and sensitivity tests to evaluate the performance of the CMPs under alternative scenarios, similar to "sensitivity runs" in a stock assessment. These include 1) a lower steepness value for recruitment (which was removed from the reference set), 2) increased natural variability in recruitment, 3) removal of catch-at-length data from the fitting process, 4) an assumed 1% annual increase in catchability in the historical period, 5) an assumed 1% annual increase in catchability in the projection period, 6) a scenario with 10% underreporting of catch, 7) climate change effects in the projection period through directional trends in the recruitment variability, 8) a test for impacts of alterations to the minimum size limit, and 9) evaluating the impact of a longer management cycle length (four years instead of three).

Management objectives

The N-SWO MSE currently includes 17 key performance metrics as an initial benchmark for evaluation of the Commission's selected management objectives. **Appendix A** shows the current management objectives and performance metrics based on input received from Panel 4 in March 2023. Additional input is now requested to provide input on the key performance metrics that will be used in the CMP ranking and selection process.

Candidate Management Procedures

The SCRS Swordfish Species Group is working collaboratively to develop and test a number of CMPs. All CMPs currently assume a 3-year management cycle and calculate a single total allowable catch (TAC) for the North Atlantic. Existing CMPs include both model-based and empirical examples (empirical CMPs use indices of abundance to directly set the TAC rather than putting them through a statistical model). The North Atlantic albacore MP (Rec. 21-04) is model-based, whereas the Atlantic bluefin tuna MP (Rec. 22-09) is empirical. The 13 current CMPs are described in **Appendix B**. CMPs are tuned to 51%, 60%, and 70% probability of being in the Kobe green quadrant in years 1-10 (i.e., the PGK_{SHORT} performance metric). Tuning means that all CMPs must achieve this performance standard. Any CMPs that do not achieve the Safety minimum threshold (i.e. less than 15% probability of breaching the limit reference point) are either eliminated from the CMP set or modified until they achieve the Safety minimum standard. Performance against other objectives is then compared. The proposed schedule for CMP implementation is included in **Appendix C,** and includes data requirements for each step, as well as a schedule for review of the MSE model assumptions.

Preliminary results

Included here are the preliminary performance results for select CMPs in development. The full suite of results for all 17 performance metrics are available online (see Other resources below).

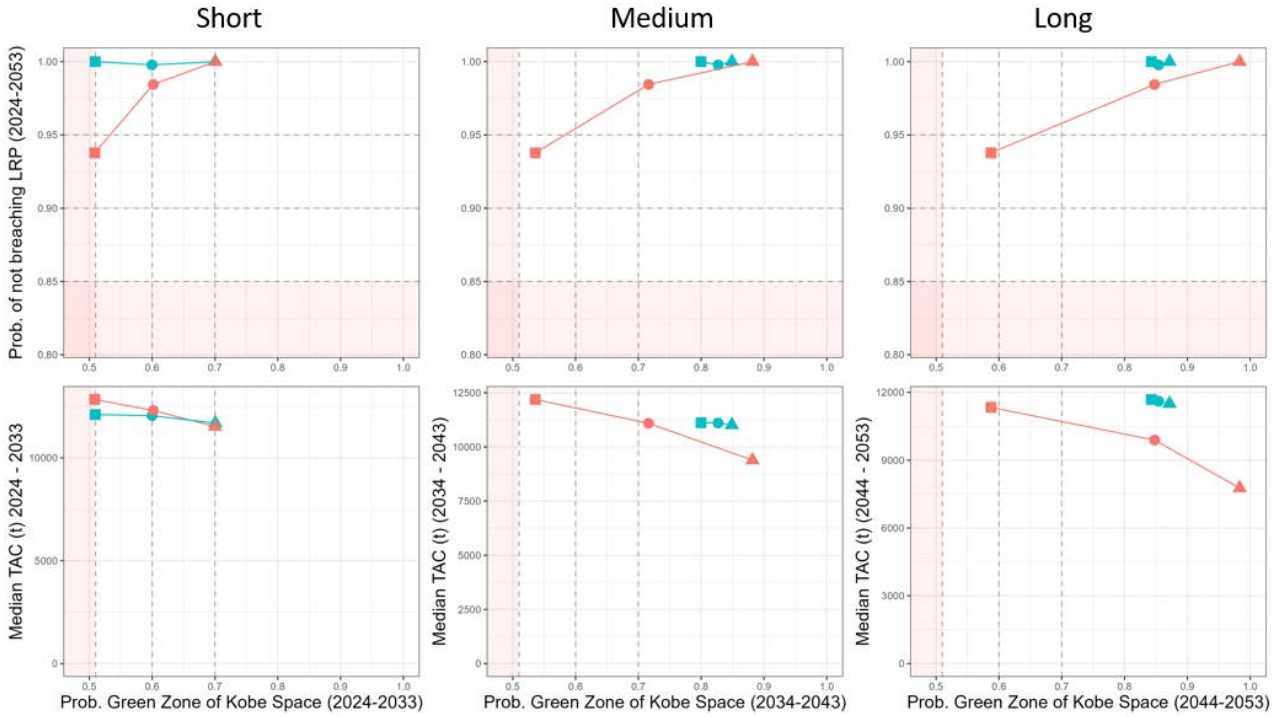

Figure 1. Plots showing the key tradeoffs between Status, Safety, and Yield for two CMPs. The top row depicts the Status *vs* Safety tradeoff, with PGK (status) for the three time periods (short, medium, long) on the horizontal axis and LRP (Safety) on the vertical axis. The bottom row depicts the Status *vs* Yield tradeoff, with PGK on the horizontal axis and median TAC on the vertical axis. For all plots, square symbols indicate CMPs tuned to 51% PGK in the short time period (years 1-10), while circles and triangles represent the same CMPs tuned to 60% and 70% PGK in the short time period, respectively.

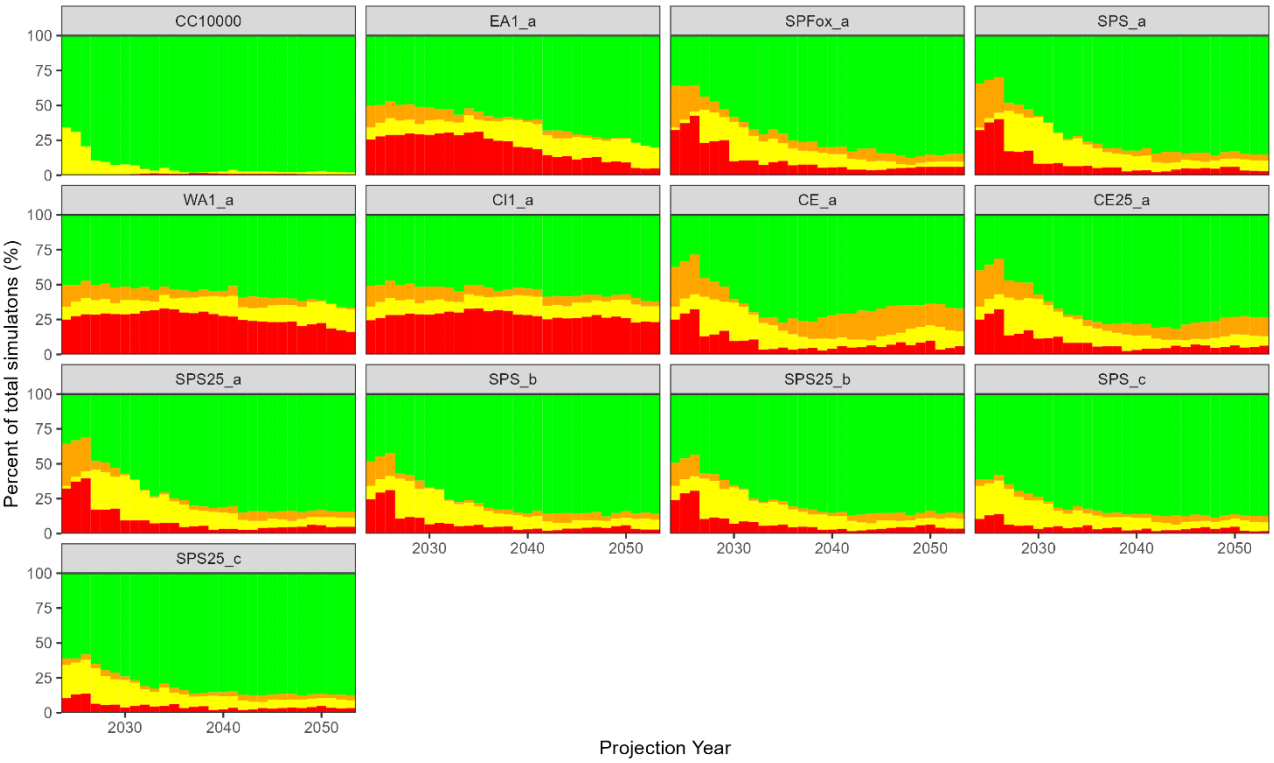

Figure 2. Kobe time plot showing the median percentage (vertical axis) of simulations across all operating models that fall in each of the Kobe quadrants in each projection year (horizontal axis). Green indicates that the stock is neither overfished nor subject to overfishing. Orange means that the stock is subject to overfishing but not overfished. Yellow indicates that the stock is overfished but not subject to overfishing. Red means that the stock is both overfished and subject to continued overfishing.

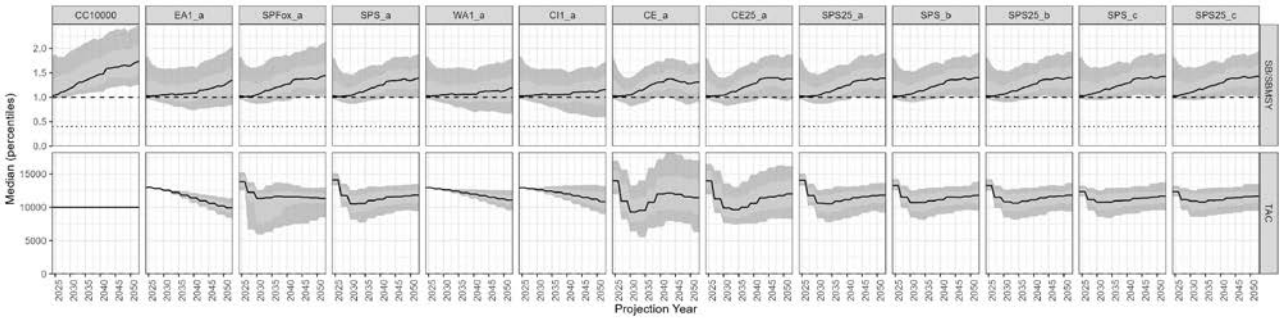

Figure 3. Trajectory of a) spawning stock biomass (SSB) relative to SSB at MSY (top row) and yield (bottom row) for 13 CMPs. Results are summarized across all operating models.

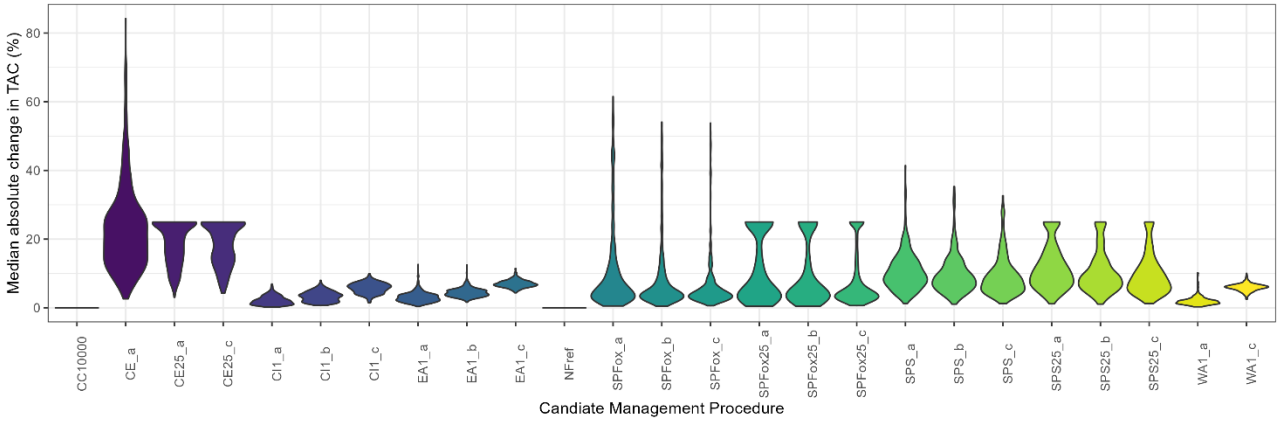

Figure 4. Violin plot for the change in TAC between management cycles, ranging from 0% change at the bottom to 85% change at the top. The width of the violin plot indicates the proportion of data points that are in each region of the plot (i.e., wide areas of the plot indicate a relatively large number of data points in that region, while narrow areas of the plot indicate few data points).

Next steps and key decisions

Two remaining Panel 4 meetings are scheduled in 2023 (30 June and 10-11 October) for the exchange of information between the SCRS and Panel 4 in advance of the 2023 Commission meeting. The Swordfish Species Group will also use ambassador sessions to help improve understanding of the MSE and answer questions. An ambassador session was held on 12 June 2023, with the next scheduled for 5 October 2023. At the 30 June 2023 Panel 4 meeting, feedback is requested from managers on the following decisions:

a) Choice of a key performance metrics, timeframes, and minimum/maximum acceptable thresholds (if applicable) for each of the Status, Safety, Stability, and Yield objectives

There are currently 7 Status performance metrics, 2 Stability performance metrics, and 4 performance metrics each for the Safety and Yield objectives.

- Which performance metrics would Panel 4 like to select as the key metrics for reporting CMP results and CMP ranking? The SCRS will continue to evaluate all performance metrics, but Panel 4 must consider whether there should be a subset of primary metrics to include in presentations with secondary metrics available elsewhere.

b) Choice of tuning objective, including timeframe

To illustrate the tradeoffs among status probability values, CMPs are currently tuned to 51%, 60%, and 70% probability of being in the Kobe green quadrant in years 1-10 (i.e., PGK_{SHORT} performance metric), as agreed by Panel 4 at the March meeting. All CMPs tuned to these probabilities must also achieve the minimum threshold for Safety (less than 15% probability of breaching the LRP), otherwise they are discarded from further development.

- Does Panel 4 approve of this procedure for tuning?

c) Definition of minimum threshold for TAC change between management cycles, if desired

At each application of the MP, it may be desirable to set a minimum bound for TAC change for administrative purposes. A minimum TAC change is part of the bluefin MP but not the albacore MP.

- Would Panel 4 like to set a minimum level for TAC change for all CMPs, and if so, what tonnage?

d) Prioritization of robustness and sensitivity tests

Nine robustness and sensitivity tests have been identified and Panel 4 may desire for these tests to be used while selecting an MP. The SCRS will be able to develop some of these tests in 2023.

- Does Panel 4 have a preference on which of the robustness and sensitivity tests are to be developed in 2023?

Other resources

North Atlantic Swordfish MSE splash page
North Atlantic Swordfish MSE interactive Shiny App (includes preliminary results)
Harveststrategies.org MSE outreach materials (multiple languages)

Appendix A

Current management objectives and corresponding performance metrics based on input received at the March 2023 Panel 4 meeting

Management objectives (Res. 19-14)	*Proposed corresponding performance metrics*
Status The stock should have a [51, 60, 70]% or greater probability of occurring in the green quadrant of the Kobe matrix.	**PGK_{SHORT}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F < F_{MSY}$) in years 1-10 **PGK_{MED}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F < F_{MSY}$) in years 11-20 **PGK_{LONG}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F < F_{MSY}$) in years 21-30 **PGK_{ALL}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F < F_{MSY}$) over years 1-30 **PGK_{30}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F < F_{MSY}$) in year 30 **POF:** Probability of overfishing ($F > F_{MSY}$) over years 1-30 **PNOF:** Probability of not overfishing ($F < F_{MSY}$) over years 1-30
Safety There should be a [5, 10, 15]% or less probability of the stock falling below B_{LIM} ($0.4*B_{MSY}$) at any point during the 30-year evaluation period.	**LRP_{SHORT}**: Probability of breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) in any of years 1-10 **LRP_{MED}**: Probability of breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) in any of years 11-20 **LRP_{LONG}**: Probability of breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) in any of years 21-30 **LRP_{ALL}**: Probability of breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) in any of years 1-30
Yield Maximize overall catch levels.	**C1** – TAC in the first management cycle (years 1-3) **$AvTAC_{SHORT}$** – Median TAC (t) over years 1-10 **$AvTAC_{MED}$** – Median TAC (t) over years 11-20 **$AvTAC_{LONG}$** – Median TAC (t) over years 21-30
Stability Any increase or decrease in TAC between management periods should be less than [25]%. [also test no stability limitation]	**VarC** – Median variation in TAC (%) between management cycles over years 1-30 **MaxVarC** – Maximum variation in TAC (%) between management cycles over years 1-30

Appendix B

Candidate Management Procedures (CMPs) currently under development

MP	*Type*	*PGK tuning target*	*Indices*	*Description*
CC10000	Empirical	-	-	Constant TAC at 10,000 t
CE_a	Empirical	51%	Combined	Constant Exploitation Rate
CE25_a	Empirical	51%	Combined	Constant Exploitation Rate with a maximum absolute change in TAC of 25%
CI1_a	Empirical	51%	Combined	Index ratio method using the Combined Index, smoothed and scaled by the inverse variance before averaging
EA1_a	Empirical	51%	SP, MO, PO	Index ratio method using the SP, MO, and PO indices, smoothed and scaled by the inverse variance before averaging
WA1_a	Empirical	51%	CA, US, CT, JP	Index ratio method using the CA, US, CT, and JP indices, smoothed and scaled by the inverse variance before averaging
SPFox_a	Model	51%	Combined	Fox Surplus Production with an HCR
SPS_a	Model	51%	Combined	Schaefer Surplus Production with an HCR
SPS_b	Model	60%	Combined	Schaefer Surplus Production with an HCR
SPS_c	Model	70%	Combined	Schaefer Surplus Production with an HCR
SPS25_a	Model	51%	Combined	Schaefer Surplus Production with an HCR with a maximum absolute change in TAC of 25%
SPS25_b	Model	60%	Combined	Schaefer Surplus Production with an HCR with a maximum absolute change in TAC of 25%
SPS25_c	Model	70%	Combined	Schaefer Surplus Production with an HCR with a maximum absolute change in TAC of 25%

Appendix C

Proposed schedule for data provision, updating MPs and stock assessments

		Activity					*Data inputs*			
Year	Management cycle	MP run	MP advice implemented	Stock assessment	MSE Review	Exceptional circumstances evaluated	Combined index	Other CPUEs	Catch data	Exceptional circumstance indicators
2023		x					x	x	x	x
2024	1		x			x				x
2025	1					x				x
2026	1	x				x	x		x	x
2027	2		x			x				x
2028	2			x (alternative)		x				x
2029	2	x		x		x	x	x	x	x
2030	3		x	x (alternative)		x				x
2031	3					x				x
2032	3	x			x	x	x		x	x

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. 19-14 for N-SWO).

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 tests 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 will be typically less plausible and/or influential on performance.