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Western Atlantic Skipjack Management Strategy Evaluation (MSE): Background, Structure, Results and further Development

(Prepared by the Contractor in coordination with the SCRS Chair and the Western Skipjack Rapporteur)

This document describes core concepts of the Western Atlantic Skipjack Tuna MSE. The intention is to provide sufficient knowledge to facilitate discussion among scientists, fishery managers and other stakeholders, commencing with the First Intersessional Meeting of Panel 1 Western Skipjack MSE (20-21 February 2024) and continuing in the lead up to scheduled adoption of a management procedure (MP) in November 2024. This document summarizes the MSE structure, process, preliminary results, and feedback requested to the First Intersessional Panel 1 meeting held in February.

1. Background

The SCRS's Tropical Tunas Species Group has been developing an MSE framework for West Atlantic skipjack (SKJ-W) since 2020. In 2015, the Commission called for adoption of an MP for SKJ-W and seven other priority stocks based on an MSE (Rec. 15-07). This call for an MSE has been echoed in every ICCAT tropical tunas measure since 2016, with Rec. 16-01 setting initial performance indicators for tropical tunas. While the East Atlantic skipjack stock is included in the multistock MSE with bigeye and yellowfin tunas, western Atlantic skipjack has been earmarked for its own MSE since the Commission adopted the "First Draft Roadmap for the Development of MSE and Harvest Control Rules (HCR)" in 2016; this is because western skipjack tuna are caught predominantly in a single-stock fishery.

External experts launched the MSE work in 2020 (SCRS/140/2020) and since then, MSE development has been conducted by the SCRS (SCRS/2022/097, SCRS/2022/180, SCRS/2023/169). The Commission adopted conceptual management objectives for SKJ-W in 2022 (Res. 22-02), and started to operationalize those objectives at the Second Intersessional Meeting of Panel 1 on Western Skipjack MSE held on 5 May 2023. The MSE work is on track for ICCAT to adopt an MP in 2024, in accordance with the Commission's workplan "Revised Roadmap for the ICCAT MSE processes adopted by the Commission in 2023".

Based on that, the general objective of this document is to provide sufficient knowledge to facilitate discussion among scientists, fishery managers and other stakeholders involved, directly or indirectly, on the development of SKJ-W MSE. As many of the technical elements of the MSE are now in advanced development or even complete, the SCRS is seeking guidance and feedback from Panel 1 on some key elements as outlined in Section *5. Feedback Requested* of this document. To facilitate the discussion, the next sections of this document will address and present a summary of the results achieved so far in the SKJ-W MSE.

2. MSE Overview

The SKJ-W MSE is built using an open-source MSE software package called openMSE. The package can input information from assessment models built with the Stock Synthesis framework (Report of the 2022 Skipjack Stock Assessment Meeting, 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.

2.1 Indices of Abundance

The western skipjack stock occurs from the U.S. coast to the southern Brazilian coast. Data from five different indices (baitboat – Brazil recent and earlier period, Brazil handline, Venezuela purse seine, and U.S. longline) are used to condition the MSE. On average, Brazil takes approximately 90% of the total skipjack catch in the West Atlantic, with the bulk of remaining catches (7% on average) taken by Venezuela. The MSE's historical period is from 1952 through to 2020, including observed catches for 2021 and 2022, and projections cover the subsequent 30 years.

2.2 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 SKJ-W MSE includes nine main OMs (i.e., the "reference set or grid of OMs") based on two major sources of uncertainty:

1. Recruitment/steepness: a measure of the adult biomass relative to the number of young they produce; reflects stock productivity (three options);

2. Growth vector: reflects the alternative biological parameters of the population, including different combinations of growth rate, maximum size, and natural mortality (three options).

The nine OMs allow for all combinations of these options (3x3=9). These 9 OMs were derived from the last stock assessment of the SKJ-W conducted in 2022 (Report of the 2022 Skipjack Stock Assessment Meeting). Thus, reflecting the same decision made during the last Stock Assessment, the nine OMs scenarios are considered to be equally plausible, so they are equally weighted in this MSE. These nine OMs together make up the reference set of OMs.

There will also be two sets of "robustness" OMs to evaluate less likely but still possible scenarios, similar to more extreme "sensitivity runs" in a Stock Assessment. These include 1) TAC overages (i.e., 10%, 20%) due to implementation error and 2) a to-be-developed scenario to reflect potential Climate Change impacts. Since only the implementation error scenarios have been run to date, there are currently 18 robustness OMs (9x2=18).

2.3 Management Objectives

The SKJ-W MSE currently includes twenty (20) key performance indicators as an initial benchmark for evaluation of the Commission's four agreed management objectives (see **Appendix 1**). The limit reference point (B_{LIM}) is set at 40%*SSB_{MSY} for western skipjack, as has been done for other stocks, including North Atlantic swordfish, North Atlantic albacore and Atlantic bluefin tuna. The target reference point is set at SSB_{MSY}.

2.4 Candidate Management Procedures (CMPs)

There are currently eight CMPs for western skipjack in two main categories – empirical index-based or assessment model-based. Per Panel 1's guidance, all use a 3-year management cycle and calculate a single Total Allowable Catch (TAC) for the West Atlantic. The CMPs use a 2-year data lag, e.g. in 2024, the TAC for 2025 will be set with data available up to 2022.

– The three index-based, empirical CMPs vary the catch limits based on changes in catch per unit effort (CPUE):

  - *GB_slope:* Geromont and Butterworth index slope. A rule that modifies a time-series of catch recommendations (TAC) to achieve stable catch rates;
  - *Islope1:* Index slope tracking. A rule that incrementally adjusts the time-series of catch recommendations (TAC) to maintain a constant abundance index, and;
  - *Iratio:* Mean index ratio. A rule that adjusts the TAC based on a ratio between the most recent years of the relative abundance index and the respective prior years.

– There are five model-based CMPs which incorporate "hockey stick" HCRs. Under these HCRs, fishing is at 100% or 80% of F_{MSY} when at or above the target reference point and decreases to 10% F_{MSY} once the limit reference point is breached. See **Appendix 2**, **Figures 5 and 6**, for graphic representations of the HCRs, which illustrate how F decreases between the target and limit reference points.

CMP	*Model type*	F_{Target}
SCA01	Statistical catch-at-age	F_{MSY}, if ≥ B_{MSY}
SP01	Surplus production	F_{MSY}, if ≥ B_{MSY}
SPSS01	State-space surplus production	F_{MSY}, if ≥ B_{MSY}
SP02	Surplus production	80% F_{MSY}, if ≥ B_{MSY}
SPSS02	State-space surplus production	80% F_{MSY}, if ≥ B_{MSY}

– For comparison purposes only, constant catch scenarios of 20,000, 30,000 and 40,000 t are also tested. For reference, the 2022 catch was 21,383 t.

See **Appendix 2** for a detailed description of the current CMPs evaluated in the SKJ-W MSE.

3. Results

Draft final performance results are shown for the eight CMPs and constant catch comparisons. All results presented here assume perfect TAC implementation. None of the model-based CMP results shown here use a restriction on TAC change from one management cycle to the next. The full suite of results, including implementation error robustness tests, is available in the online interactive application (see Other Resources below).

Most CMPs result in a high probability of being in the Kobe green quadrant into the future, with the exception of the constant catch CMPs with TACs greater than or equal to 30 kt. Similarly, all but the constant catch CMPs greater than or equal to 30 kt display a very constant trend, with the stock continuing to be neither overfished, nor subject to overfishing.

Regarding Status performance indicators, with the exception of CMPs based on constant catches, all others presented probabilities greater than 70% of the stock remaining in the green quadrant of Kobe plot ("PGK") throughout the time period. Regarding Safety performance indicators, in general, the CMPs based on models and/or empirical indices showed satisfactory performance, with probabilities of the stock breaching B_{lim} of less than 10%. In the case of Stability performance indicators, the CMP based on the Statistical Catch-at-Age model showed the greatest variations in TAC.

4. Workplan for 2024

The proposed workplan is described in a hierarchical manner below, for the evolution and completion of the SKJ-W MSE during 2024.

1) Present and receive Commission feedback on the current SKJ-W MSE progress at the First Intersessional Meeting of Panel 1 Western Skipjack MSE (20-21 February 2024);
2) Initiate a series of online meetings, as needed, of the Tropical Tunas Technical Sub-group on MSE to guide the work intersessionally, with review during meetings of the Tropical Tuna Species Group (during March 2024);
3) Share Panel 1's recommendations with the SCRS during the Yellowfin Data Preparatory Meeting (8-12 April 2024), including an action plan and methodological proposal for addressing the feedback;
4) Update the SKJ-W MSE following the action plan and methodology defined and discussed during the Yellowfin Data Preparatory Meeting (between April and July 2024);
5) Present the SKJ-W MSE evolution to the SCRS during the Yellowfin tuna Stock Assessment Meeting (8-12 July 2024), including the progress and evolution achieved up to the moment of this meeting, following a previously approved action plan;
6) Implement new robustness OMs to incorporate possible effects of Climate Change within the scope of the SKJ-W MSE (between July and August 2024);
7) Using the abundance indices updated through 2022 by each of the CPCs and presented during the Yellowfin tuna Stock Assessment meeting, provide updated performance projections of the CMPs, including the TAC for the initial management period (between August and September 2024);

8) Present the draft final SKJ-W MSE results to the SCRS group during the SCRS Tropical Tunas Species Group Meeting (16-21 September 2024) for adoption by the Species Group as well as the SCRS at Plenary;
9) Additional analytical work to be carried out after the SCRS Plenary meeting will follow a plan approved by the SCRS during the Plenary. Prepare communication materials to be used at the 24th Special Meeting of the ICCAT Commission (between September and November 2024);
10) Present the SKJ-W MSE final results to the ICCAT Commission, Panel 1, for consideration for MP adoption, during the 24th Special Meeting of the ICCAT Commission (11-18 November 2024).

5. Feedback Requested

At the First Intersessional Panel 1 Meeting held in February 2024, feedback is requested from managers on:

Decision Point 1: Operational Management Objectives

The SCRS welcomes feedback from Panel 1 to finalize operational management objectives for western skipjack tuna:

- Safety - Maximum acceptable probability of the stock falling below B_{LIM} ($0.4*SSB_{MSY}$) at any point during the 30-year projection period. The probability is currently set at 10%, but during the First Intersessional Meeting of Panel 1 (27-31 March 2023), the Commissioners had indicated that it could be considered to reduce that value to 5%;

- Stability – Maximum acceptable percent change in TAC between management periods, as well as whether or not this maximum acceptable change should be the same for increases as for decreases in TAC, and (for model-based CMPs) whether such a restriction should be imposed regardless of whether or not stock biomass is below or above B_{MSY}. At the Second Intersessional Meeting of Panel 1 on Western Skipjack MSE, Panel 1 expressed its interest in testing the CMPs with and without a 20% restriction on TAC changes from one management cycle to the next. They also expressed openness to asymmetric TAC change restrictions where there would be no limit on TAC decreases if $B_{current}<B_{MSY}$.

Decision Point 2: Candidate Management Procedures

There are currently eight CMPs developed and implemented for SKJ-W MSE. The SCRS welcomes Panel 1's guidance on its judgment of the need (a) to develop, implement, and evaluate new CMPs or (b) to reduce the current list according to Panel 1's preference based on the respective performances of each CMP.

Decision Point 3: Management Procedure Implementation Schedule

A key element of the process of MP implementation is the process of its review. Such a review can occur at regular, pre-scheduled intervals or following the declaration of exceptional circumstances. In most cases, such a review would not constitute a wholesale revision to the OM structure, full reconditioning of the OMs or substantial changes to the CMPs, though it offers that opportunity should the need arise. In most cases, such reviews could implement index revisions or relatively minor improvements to the OMs or MPs; indeed, the outcome may leave the MP unchanged. The proposed MP implementation schedule is included in **Appendix 3** for Panel 1's review and approval. It includes data requirements for each step, as well as a schedule for review of the MSE model assumptions.

Other Resources

West Atlantic Skipjack MSE interactive Shiny App (includes preliminary results)

Harveststrategies.org MSE outreach materials (multiple languages)

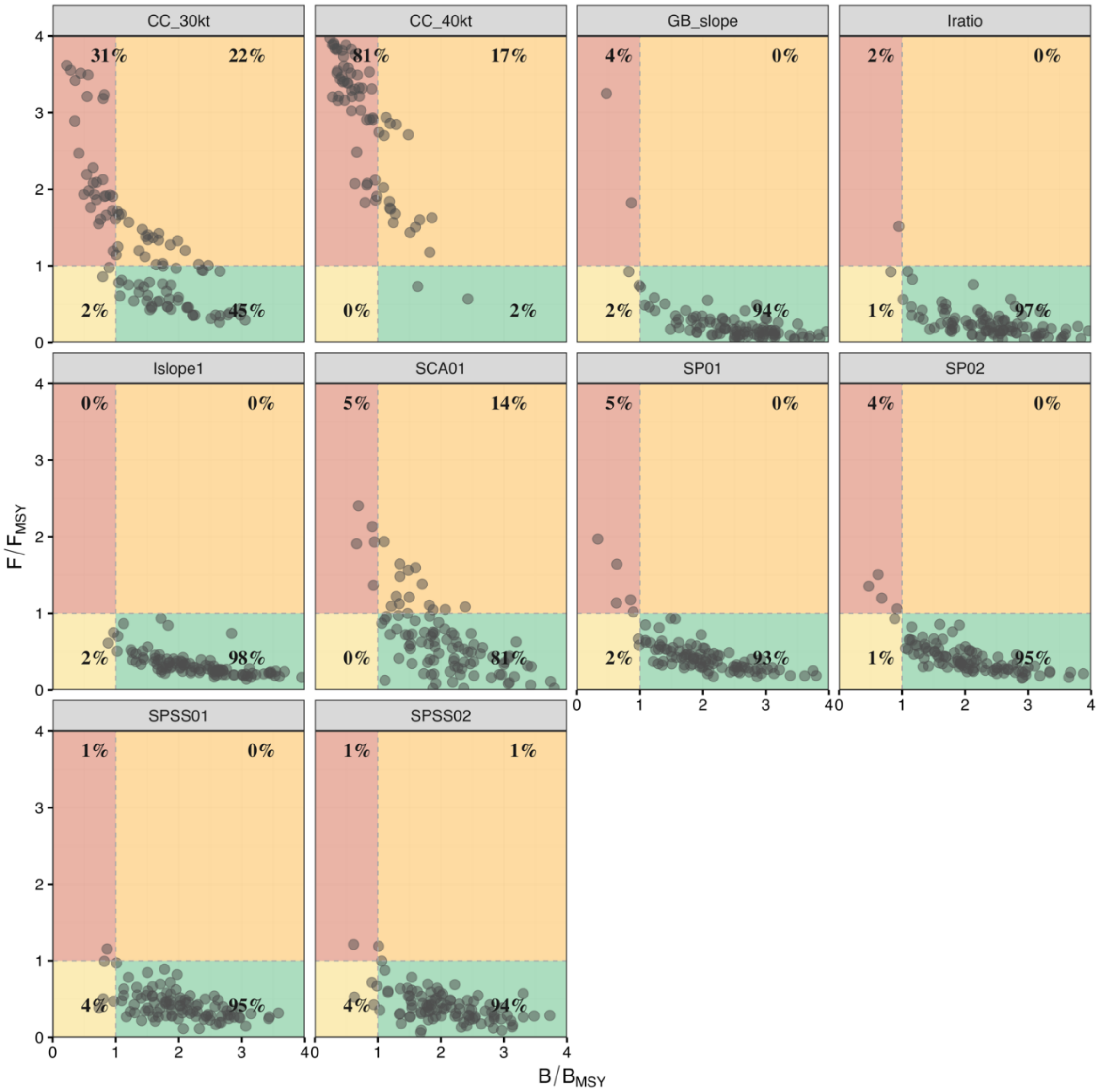

Figure 1. Probability of being in each of the Kobe plot quadrant in the last year (i.e., year 30) across the reference set of OMs with perfect TAC implementation (OMs 1-9). Each dot represents a result of one simulation average of the nine OMs.

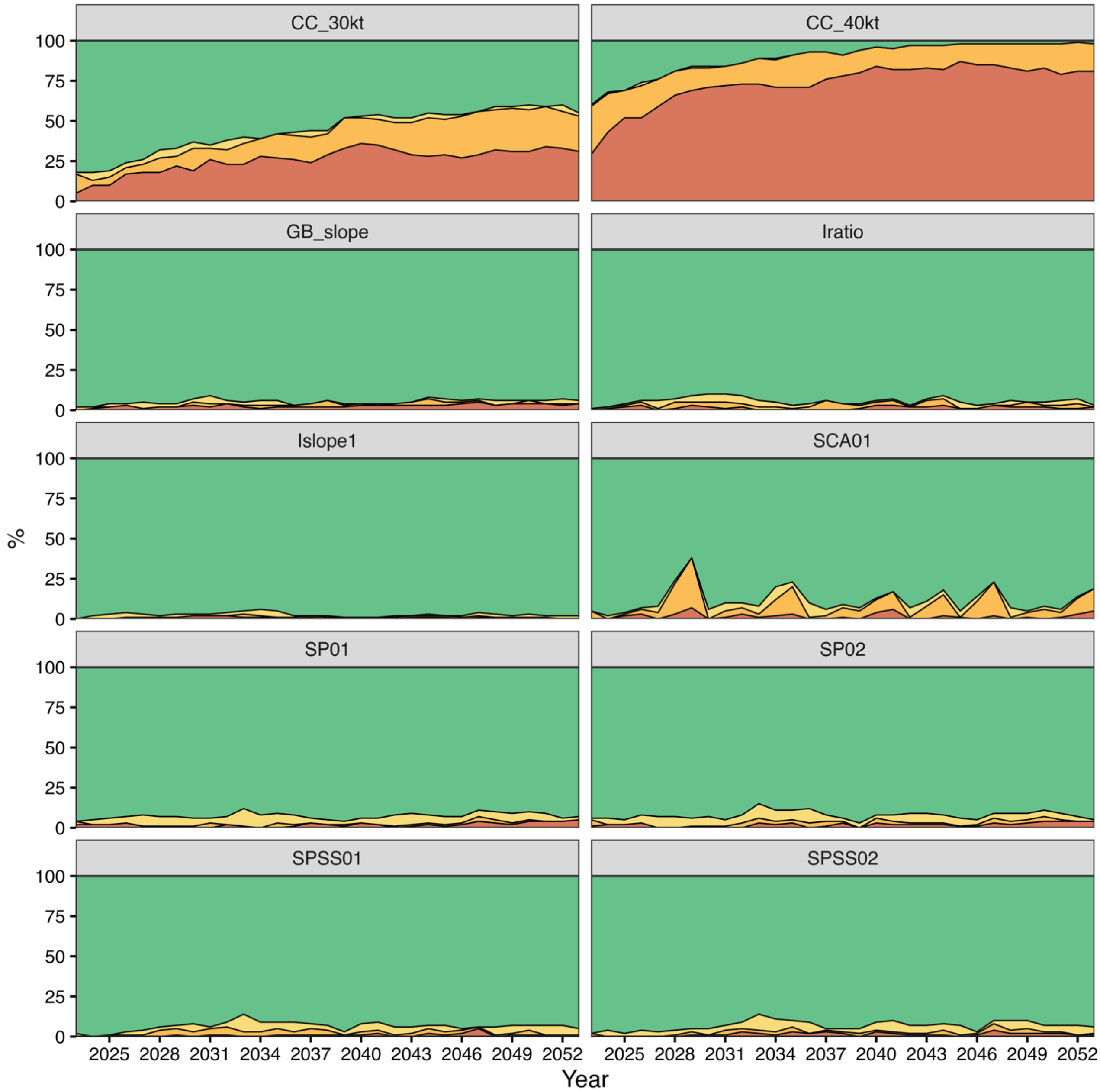

Figure 2. Probability of being in each of the Kobe plot quadrant through years across the reference set of OMs with perfect TAC implementation (OMs 1-9).

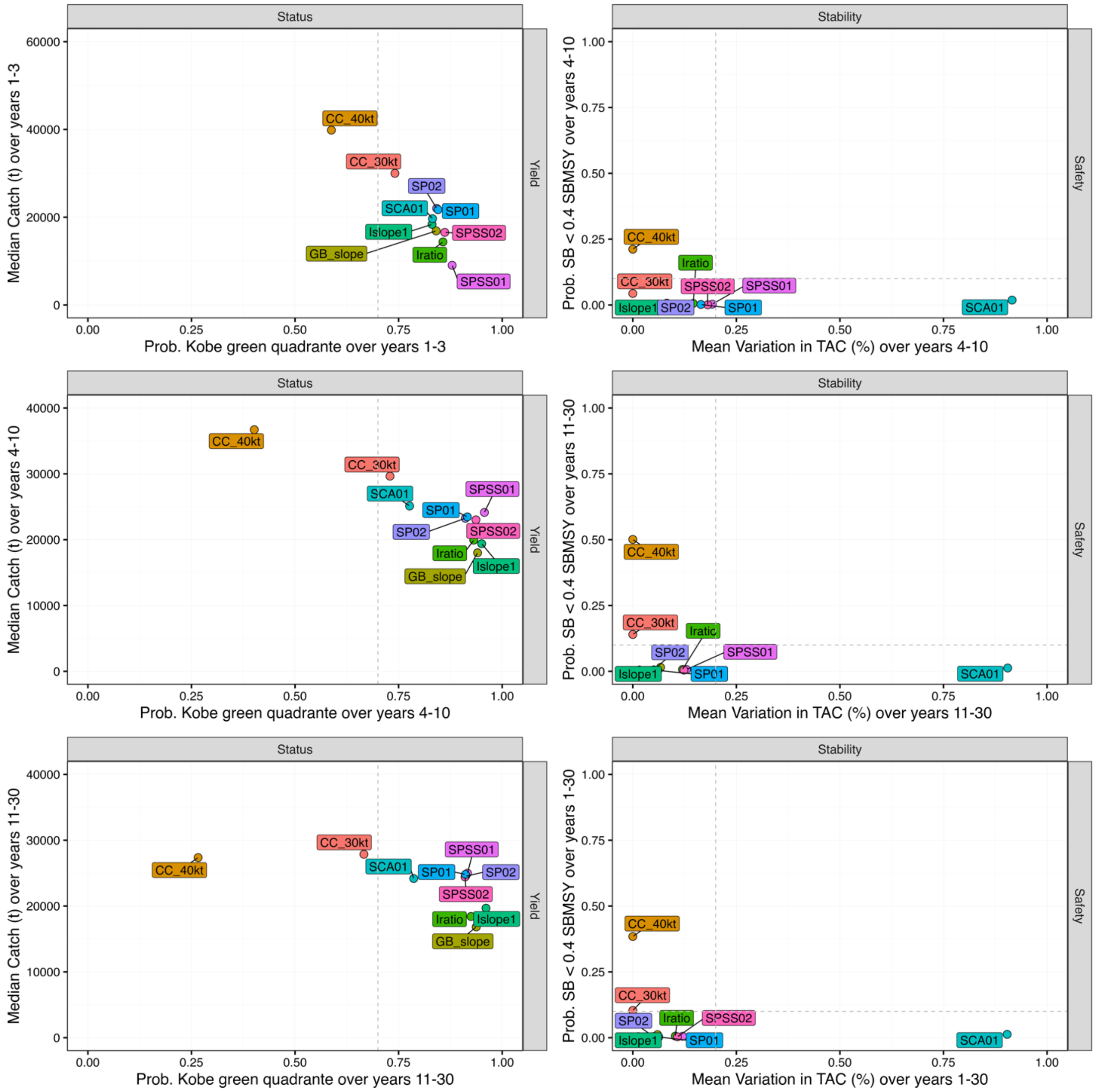

Figure 3. Plots showing the key tradeoffs between Status, Safety and Yield for all CMPs tested in the SKJ-W MSE. The dotted lines indicate the management objectives set by Panel 1.

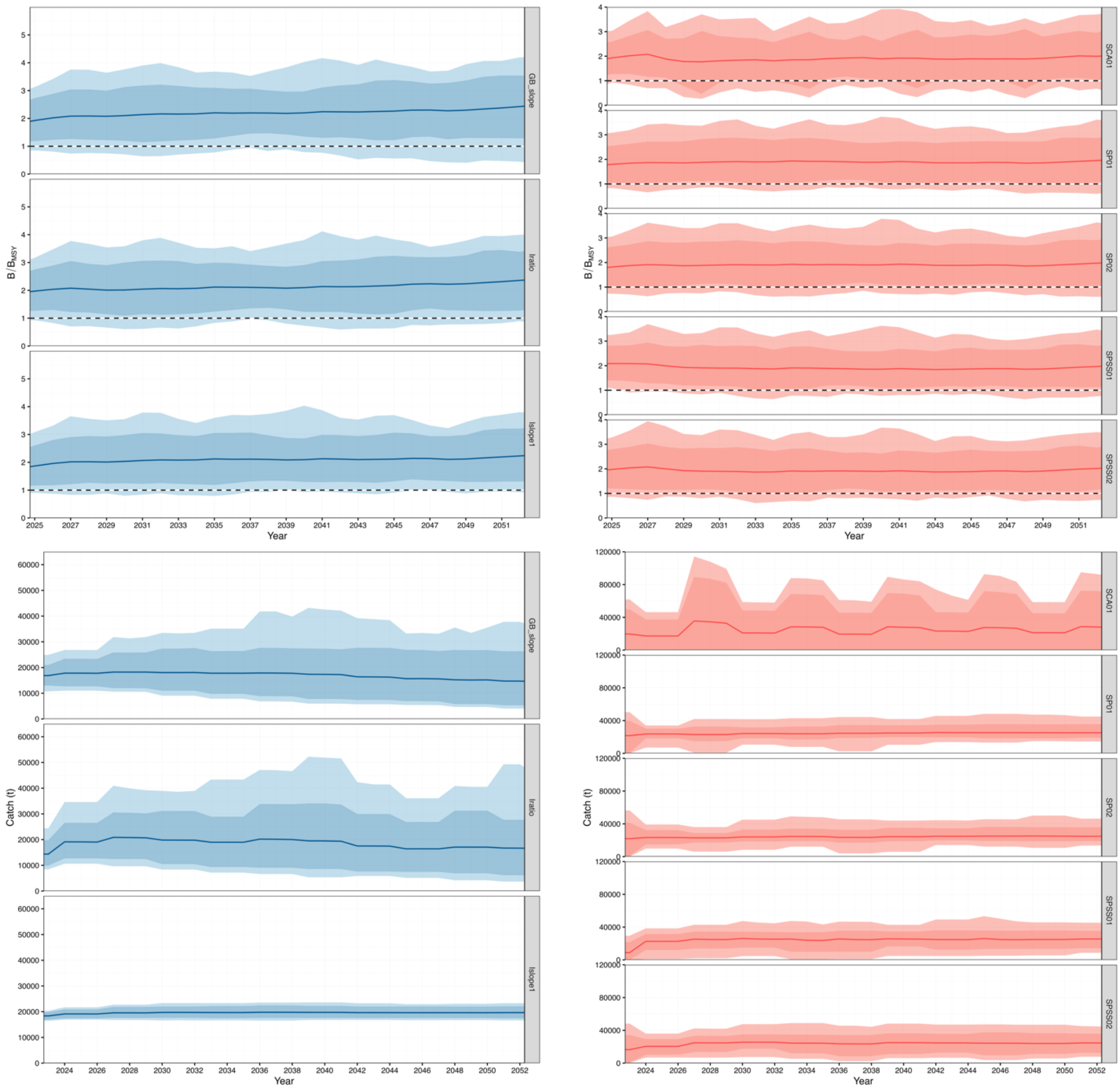

Figure 4. Trajectory of a) biomass (B) relative to B at MSY – top row, and b) yield – bottom row for 8 CMPs (empirical CMPs in blue and model-based CMPs in red).

Appendix 1

Management Objectives (from Res. 22-02 and the Panel 1 meeting in May 2023) and the current suite of Corresponding Performance Indicators

Management Objectives (Res. 22-02)	*Proposed corresponding performance indicators*
Status The stock should have a 70% or greater probability of occurring in the green quadrant of the Kobe matrix using a 30-year projection period as determined by the SCRS.	**PGK_{short}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F<F_{MSY}$) in years 1-3 **PGK_{medium}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F<F_{MSY}$) in years 4-10 **PGK_{long}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F<F_{MSY}$) over years 11-30 **PGK_{all}**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F<F_{MSY}$) over years 1-30 **POF:** Probability of $F>F_{MSY}$ over years 1-30 **PNOF:** Probability of $F<F_{MSY}$ over years 1-30
Safety There should be no greater than [10%][1] probability of the stock falling below B_{LIM} ($0.4*SSB_{MSY}$) at any point during the 30-year projection period.	**LRP_{short}**: Probability of breaching the limit reference point (i.e., $SSB<0.4*SSB_{MSY}$) over years 1-3 **LRP_{medium}**: Probability of breaching the limit reference point (i.e., $SSB<0.4*SSB_{MSY}$) over years 4-10 **LRP_{long}**: Probability of breaching the limit reference point (i.e., $SSB<0.4*SSB_{MSY}$) over years 11-30 **LRP_{all}**: Probability of breaching the limit reference point (i.e., $SSB<0.4*SSB_{MSY}$) over years 1-30 **$nLRP_{short}$**: Probability of not breaching the limit reference point (i.e., $SSB<0.4*SSB_{MSY}$) over years 1-3 **$nLRP_{medium}$**: Probability of not breaching the limit reference point (i.e., $SSB<0.4*SSB_{MSY}$) over years 4-10 **$nLRP_{long}$**: Probability of not breaching the limit reference point (i.e., $SSB<0.4*SSB_{MSY}$) over years 11-30 **$nLRP_{all}$**: Probability of not breaching the limit reference point (i.e., $SSB<0.4*SSB_{MSY}$) over years 1-30
Yield Maximize overall catch levels in the short (1-3 years), medium (4-10 years) and long (11-30 years) terms.	**AvC_{short}** – Median catches (t) over years 1-3 **AvC_{medium}** – Median catches (t) over years 4-10 **AvC_{long}** – Median catches (t) over years 11-30
Stability Any changes in TAC between management periods should be 20% or less[2].	**$VarC_{medium}$** – Variation in TAC (%) between management cycles over years 4-10 **$VarC_{long}$** – Variation in TAC (%) between management cycles over years 11-30 **Var_{all}** – Variation in TAC (%) between management cycles over years 1-30

[1] The probability of breaching B_{LIM} could be reduced to 5% at a later date was indicated at the Panel 1 May 2023 meeting.
[2] CMPs should also be tested with no restriction on TAC changes from one management cycle to the next as stated at the Panel 1 May 2023 meeting. Openness to asymmetric TAC change restrictions was also expressed where there would be no limit on TAC decreases if $B_{current}<B_{MSY}$

Appendix 2

Details of Selected CMPs for SKJ-W MSE

1. Empirical index-based CMPs

For SKJ-W MSE, as described before, three empirical index-based CMPs were evaluated: *Iratio*, *Islope1*, and *GB_slope*. These three CMPs structures the adjustment of the TAC for a given year (y+1), based on the trends observed in the abundance indices estimated for the fish stock in a previous pre-defined period. In general, when positive trends are observed, that is, increasing abundance index, positive adjustments to the TAC are proposed; In the case of negative, decreasing trends in the abundance index, the proposed adjustment in the TAC follows the same fate.

The *Iratio* CMP, already incorporating the time lag in data available (e.g. two-years data lag, as described before, e.g. in 2024, the TAC for 2025 will be set with the data available up to 2022) sets the TAC as:

$$TAC_{y+1} = \frac{\alpha}{\beta} C_{y-2}$$

where α is the mean of the abundance index in the most recent two years of the time-series, e.g. 2021-2022; β is the mean of the abundance index in the three years preceding those years for α, e.g. 2018-2020; *C* is the observed catch, and *y* is the indexed year.

The *Islope1* and *GB_slope* CMPs also already incorporate the time lag in data available, calculating the TAC as:

$$TAC_{y+1} = (1 + \theta\lambda) C_{y-2}$$

where, θ is the slope of log(abundance index) in the most recent 3 years of the time-series; λ is a tuning parameter (λ= 0.2 for *Islope1*, and λ= 1 for *GB_slope*); *C* is also the observed catch, and *y* is the indexed year. Additionally, *GB_slope* includes a constraint rule where TAC cannot exceed the limits of 80-120% of the most recent catch, which tests the 20% stability objective.

2. Model-based CMPs with "hockey-stick" harvesting control rule

Three model frameworks were tested as model-based CMPs for the SKJ-W MSE: a Statistical Catch-at-Age, a Surplus Production, and a State-Space Surplus Production model. For the Statistical Catch-at-Age, an HCR based on fishing at 100% of F_{MSY} when at or above the target reference point and decreasing to 10% F_{MSY} once the limit reference point is breached, was tested (**Figure 5**; HCR_A). For the Surplus Production models, with or without State-Space structure, two HCRs were implemented and tested: (a) based on the same rule used for the Statistical Catch-at-Age model (**Figure 5**), and; (b) a second one based on fishing at 80% F_{MSY} when at or above the target reference point and also decreasing to 10% F_{MSY} once the limit reference point is breached (**Figure 6**; HCR_B).

In both cases, a combined index is used to track the relative changes in the SKJ-W population. To provide the combined index, a Tukey's running median smoother was used, the same methodology used in the SWO-N MSE (SCRS/2023/144).

For the HCR_A (e.g. SCA01; SP01; SPSS01), also incorporating the time lag in data available, the following HCR is used to set the target fishing mortality (F_{mort}):

$$F_{mort} = \begin{cases} F_{tar}, if\ B_{y-2} \geq B_{thresh} \\ F_{tar}\left(-0.5 + 1.5\frac{B_{y-2}}{B_{thresh}}\right), if\ B_{thresh} > B_{y-2} > B_{lim} \\ F_{min}, otherwise \end{cases}$$

where, F_{mort} is the proposed harvest rate; F_{tar} is defined to be equal to F_{MSY}; B_{y-2} is the estimated current biomass already incorporating the time lag in data available; B_{thresh} is the estimated biomass that corresponds to the maximum sustainable yield; B_{lim} is the limit biomass defined by Panel 1 (0.4*B_{thresh}), and; F_{min} is the minimal fishing effort estimated by 0.1*F_{msy}.

For the HCR_B (SP02, SPSS02), also incorporating the time lag in data available, the following HCR is used to set the target fishing mortality (F_{mort}):

$$F_{mort} = \begin{cases} F_{tar}, if\ B_{y-2} \geq B_{thresh} \\ F_{tar}\left(-0.367 + 1.167\dfrac{B_{y-2}}{B_{thresh}}\right), if\ B_{thresh} > B_{y-2} > B_{lim} \\ F_{min}, otherwise \end{cases}$$

where, F_{mort} is the proposed harvest rate; F_{tar} is defined to be equal to 0.8*F_{MSY}; B_{y-2} is the estimated current biomass already incorporating the time lag in data available; B_{thresh} is the estimated biomass that corresponds to the maximum sustainable yield; B_{lim} is the limit biomass defined by Panel 1 (0.4*B_{thresh}), and; F_{min} is the minimal fishing effort estimated by 0.1*F_{msy}.

Finally, the TAC for the following year is calculated as:

$$TAC_{y+1} = F_{mort} * B_{y-2}$$

In this way, the TAC for the first year (2025) of the first management cycle (2025-2027) will be estimated based on the biomass estimated from the application of the CMP to data updated until 2022.

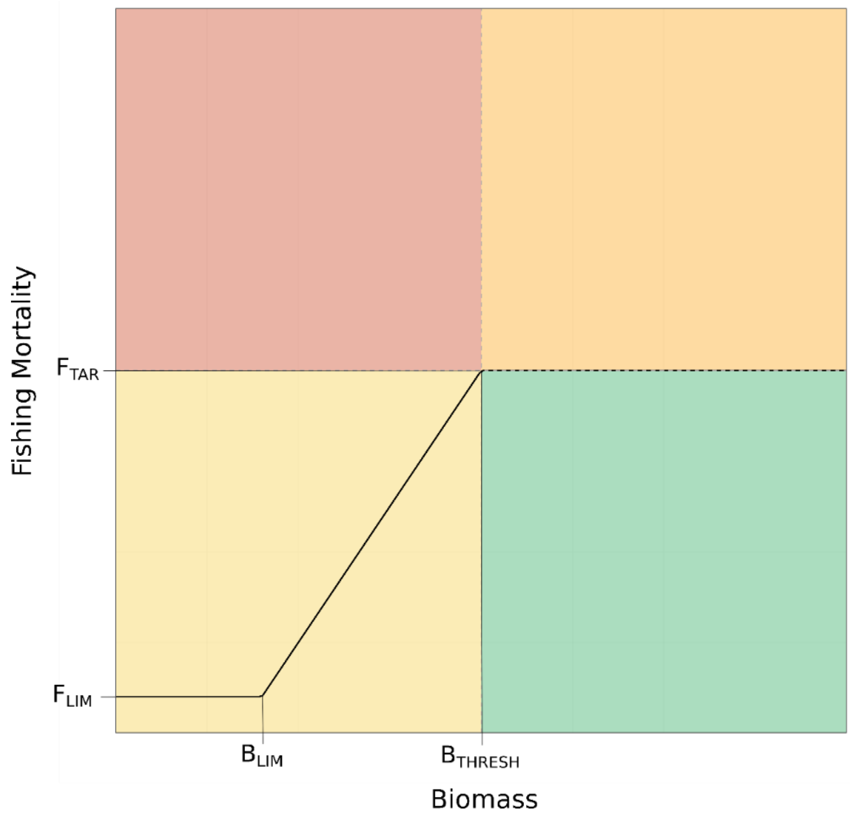

Figure 5. Generic form of the HCR, HCR_A, defined to be tested in the SKJ-W MSE.

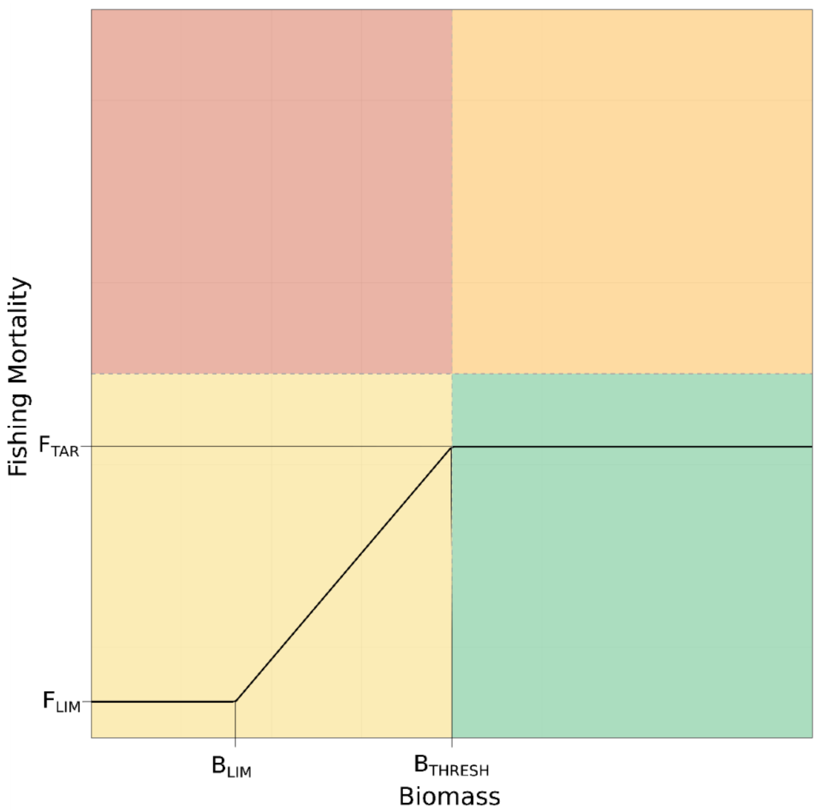

Figure 6. Generic form of the HCR, HCR_B, defined to be tested in the SKJ-W MSE.

Appendix 3

Draft Schedule for MP Implementation, assuming a Three-Year Management Cycle

	2024	*2025*	*2026*	*2027*	*2028*	*2029*	*2030*
SCRS check for exceptional circumstances		X	X	X	X	X	X
SCRS runs MP	X			X			X
Commission adopts TAC based on MP	X			X			X
TAC in effect		X	X	X	X	X	X
SCRS MP review							X
Status Check/Assessment							X
Commission assesses SCRS review and next steps							X

Appendix 4

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 a 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 MPs, the latter, more specific definition applies, but sometimes conceptual objectives are adopted first (e.g., Res. 22-02 for SKJ-W).

Management Procedure (MP): Some combination of monitoring, assessment, HCR 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 MPs 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 MPs.

Performance Indicator: 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 statistic.

Reference Grid: The OMs that represent the most important uncertainties in stock and fishing dynamics, which are used as the principal basis for evaluating CMP performance. The reference OMs 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 OMs 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 OMs that provide additional tests of CMP performance robustness. They can be used to further discriminate between CMPs. Compared to the Reference Grid OMs, the Robustness Set models will be typically less plausible and/or influential on performance.