**PA1_510/2024**
**05/11/2024 15:47**
**Original: English**

# Western Atlantic skipjack management strategy evaluation (MSE): background, overview, final results, & decision guide

*(Prepared by the Tropical Tunas Technical Sub-Group on MSE in coordination with the SCRS Chair and the Western Skipjack Rapporteur)*

This document describes core concepts and presents the final results of the western Atlantic skipjack tuna MSE. The intention is to facilitate discussions and decision-making for the adoption of a management procedure (MP) at the 24th Special Meeting of the Commission in November 2024.

## 1. Background

The SCRS's Tropical Tunas Species Group has been developing a management strategy evaluation (MSE) framework for West Atlantic skipjack (SKJ-W) since 2020. In 2015, the Commission called for adoption of a management procedure (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 multispecies 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, SCRS/2024/050, SCRS/2024/162). The Commission adopted conceptual management objectives for SKJ-W in 2022 (Res. 22-02), and worked to operationalize those objectives at the Second Intersessional Meeting of Panel 1 on Western Skipjack MSE held on 5 May 2023 and the First Intersessional Meeting of Panel 1 on Western Skipjack MSE held on 20-21 February 2024. During 2024, a series of meetings conducted within both the SCRS and Panel 1 culminated in further development of the SKJ-W MSE, including updates to catch data and abundance indices and revisions of candidate management procedures (CMPs) to improve performance. The MSE work is now complete and ready 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".

## 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, including those 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 CMPs.

### *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.-Mexico 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 30 years.

### *2.2 Operating models*

Each operating model (OM) in the MSE represents a hypothesis or plausible scenario for the dynamics of the stock and fishery. The SKJ-W MSE includes 9 main OMs (i.e., the "reference set or grid of OMs") based on two major sources of uncertainty:

1. Recruitment/steepness: a measure of how the number of young fish produced each year is related to the abundance of the adult population; reflects stock productivity (3 options)
2. Growth vector: reflects the alternative biological parameters of the population, including different combinations of growth rate, maximum size, and natural mortality (3 options)

The 9 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 decisions 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 operating models.

There are also two "robustness" OMs to evaluate less likely but still possible scenarios. These include TAC overages of 10% or 20% due to implementation error, resulting in 18 robustness OMs (9x2=18). A robustness test to evaluate potential climate change impacts will be developed in 2025.

### *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 10 CMPs, six empirical and four model-based. As 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. Full descriptions of the CMPs are available in SCRS/2024/162, but briefly, these include:

- IR: Three index ratio CMPs with different limits on TAC change. TACs are set based on the combined index but when the change of index is within the specified envelope, TAC is not changed
  - IR01: TAC change limited to 20% increase or 25% decrease
  - IR02: TAC change limited to 20%, both for increase or decrease
  - IR03: No limit on TAC change
- CE: Three constant exploitation rate CMPs with three different limits on TAC change
  - CE01: TAC change limited to 20% increase or 25% decrease
  - CE02: TAC change limited to 20%, both for increase or decrease
  - CE03: No limit on TAC change
- SP: Four model-based CMPs that use either a surplus production model or state-space surplus production model with a 100-40 hockey stick harvest control rule and an $F_{TARGET}$ of either 100%$F_{MSY}$ (**Figure 1**, on left) or 80%$F_{MSY}$ (**Figure 1**, on right)
  - SP01: Surplus production model with $F_{TARGET}$= 80%$F_{MSY}$
  - SP02: State-space surplus production model with $F_{TARGET}$= 80%$F_{MSY}$
  - SP03: Surplus production model with $F_{TARGET}$= 100%$F_{MSY}$
  - SP04: State-space surplus production model with $F_{TARGET}$= 100%$F_{MSY}$

## 3. Final results

Panel 1 provided feedback on the initial MSE results in May 2023 and at an intersessional meeting in February 2024, which the SCRS took into consideration when continuing its CMP development work. These new final results are summarized below (**Tables 1** and **2**, **Figures 2** to **4**) and described fully in document SCRS/2024/162.

The results have changed considerably since May 2023 when Panel 1 advised on operational management objectives. This is because the CMPs now use the combined index and incorporate the actual fishery data rather than simulations only. Those prior results had very low error and were overly optimistic, whereas the new results are based on the final reference set of OMs and a more thorough accounting of uncertainty. It is therefore more difficult to achieve a probability of green Kobe (PGK) of 70% for the 30-year projection period, which results in lower average yields when compared to the anterior simulations. All CMPs achieve a 90% or higher chance of not breaching the limit reference point over the entire projection period, although some CMPs are down to 88% for years 21-30. The current MSE results can be now considered final as a basis for Commission adoption of final management objectives and an MP to set the TAC for 2025 and beyond.

## 4. Decision guide

The following points should be reflected in the final MP adopted by the Commission in November:

a) Final operational management objectives (see **Appendix 1**), including:
   - Minimum acceptable threshold for the Status objective;
   - Minimum acceptable threshold for the Safety objective;
   - Maximum percentage allowable change in TAC between management periods;
   - Results for CMP relative performance are provided above in **Tables 1-2** and **Figures 2-4** and may help to inform these decisions.

b) Final CMP type:
   - There are ten remaining CMPs – IR_01, IR_02, IR_03, CE_01, CE_02, CE_03, SP_01, SP_02, SP_03, and SP_04;
   - Results for CMP relative performance are provided in **Tables 1-2** and **Figures 2-4** to inform selection.

c) MP implementation schedule:
   - A key element of the process of management procedure implementation is the process of its review. Such a review can occur at regular, prescheduled intervals or following the declaration of exceptional circumstances. In most cases, such a review would not constitute a wholesale revision to the operating model 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 operating models 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.

## 5. Other resources

West Atlantic Skipjack MSE interactive Shiny App (includes preliminary results): Under "Load an Example", select "Western Atlantic Skipjack Tuna".

Harveststrategies.org MSE outreach materials (multiple languages).

**Table 1.** Quilt table showing results for the 10 CMPs against key performance indicators for the reference set of operating models. See **Appendix 1** for performance indicator descriptions. Higher values are better for all metrics except VarC. Darker shading indicates better performance, but some of the values are very similar, despite different shading.

| MP | AvC_short | AvC_med | AvC_long | PGK_short | PGK_med | PGK_long | PGK | PNOF | nLRP_short | nLRP_med | nLRP_long | nLRP | VarCmedium | VarClong | VarC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IR_01 | 20581 | 21096 | 20065 | 0.71 | 0.72 | 0.69 | 0.70 | 0.77 | 1.00 | 0.96 | 0.88 | 0.91 | 0.01 | 0.00 | 0.00 |
| IR_02 | 20581 | 21096 | 20065 | 0.71 | 0.72 | 0.69 | 0.70 | 0.77 | 1.00 | 0.96 | 0.88 | 0.91 | 0.01 | 0.00 | 0.00 |
| IR_03 | 20581 | 21106 | 20061 | 0.71 | 0.72 | 0.69 | 0.70 | 0.77 | 1.00 | 0.96 | 0.88 | 0.91 | 0.01 | 0.00 | 0.00 |
| CE_01 | 20677 | 20609 | 20324 | 0.71 | 0.72 | 0.69 | 0.70 | 0.80 | 1.00 | 0.96 | 0.92 | 0.94 | 0.22 | 0.31 | 0.25 |
| CE_02 | 20677 | 20712 | 20641 | 0.71 | 0.72 | 0.67 | 0.69 | 0.79 | 1.00 | 0.96 | 0.91 | 0.93 | 0.21 | 0.29 | 0.23 |
| CE_03 | 20677 | 21571 | 20189 | 0.71 | 0.68 | 0.64 | 0.66 | 0.77 | 1.00 | 0.95 | 0.90 | 0.92 | 0.34 | 0.53 | 0.37 |
| SP_01 | 21616 | 22142 | 19716 | 0.70 | 0.68 | 0.71 | 0.70 | 0.78 | 1.00 | 0.94 | 0.89 | 0.92 | 0.04 | 0.02 | 0.02 |
| SP_02 | 21395 | 17649 | 15658 | 0.68 | 0.75 | 0.87 | 0.82 | 0.90 | 1.00 | 0.96 | 0.96 | 0.97 | 0.31 | 0.26 | 0.28 |
| SP_03 | 21616 | 22142 | 19716 | 0.70 | 0.68 | 0.71 | 0.70 | 0.78 | 1.00 | 0.94 | 0.89 | 0.92 | 0.04 | 0.02 | 0.02 |
| SP_04 | 21395 | 17695 | 15771 | 0.68 | 0.75 | 0.86 | 0.82 | 0.89 | 1.00 | 0.96 | 0.96 | 0.97 | 0.31 | 0.26 | 0.28 |

**Table 2.** Quilt table showing results for the 10 CMPs against TAC1 for the reference set of operating models.

| CMP | TAC1 |
|---|---|
| CE_01 | 20,559.79 |
| CE_02 | 20,559.79 |
| CE_03 | 20,559.79 |
| IR_01 | 20,000.11 |
| IR_02 | 20,000.11 |
| IR_03 | 20,000.11 |
| SP_01 | 23,891.52 |
| SP_02 | 15,378.83 |
| SP_03 | 23,891.52 |
| SP_04 | 15,332.60 |

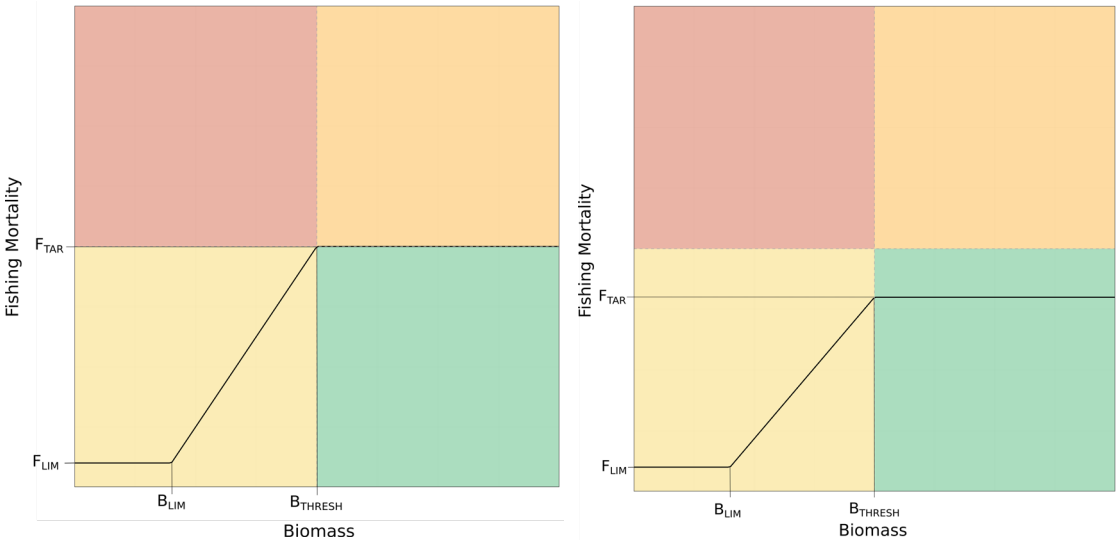


**Figure 1**. Schematic description of the harvest control rules (HCR) implemented in the model-based CMPs evaluated for the SKJ-W MSE.

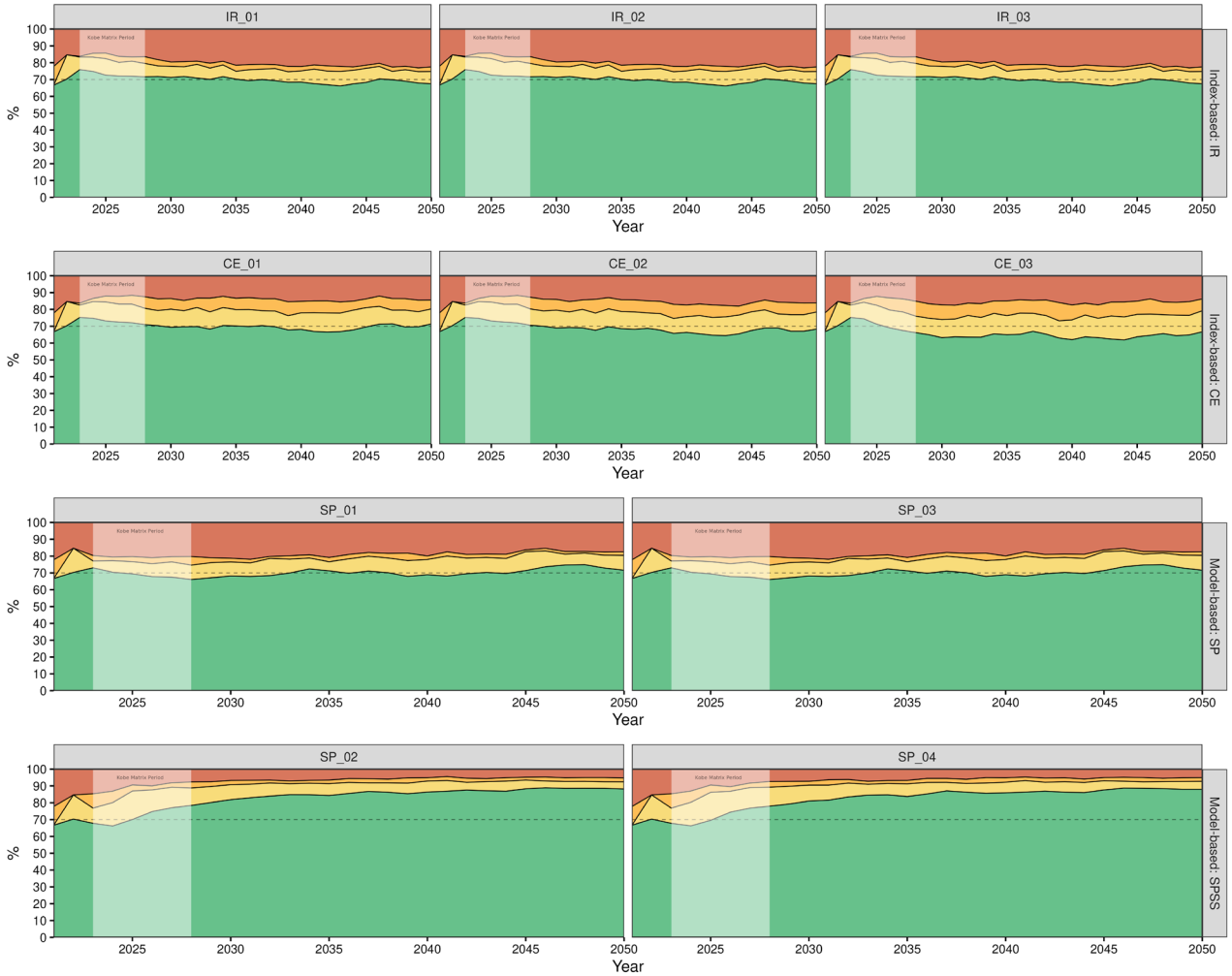


**Figure 2.** Kobe time plot showing the percentage (vertical axis) of simulations across all simulations and all reference operating models that fall in each of the Kobe quadrants in each projection year (horizontal axis). Green indicates that the stock is neither overfished nor subject to overfishing. 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.

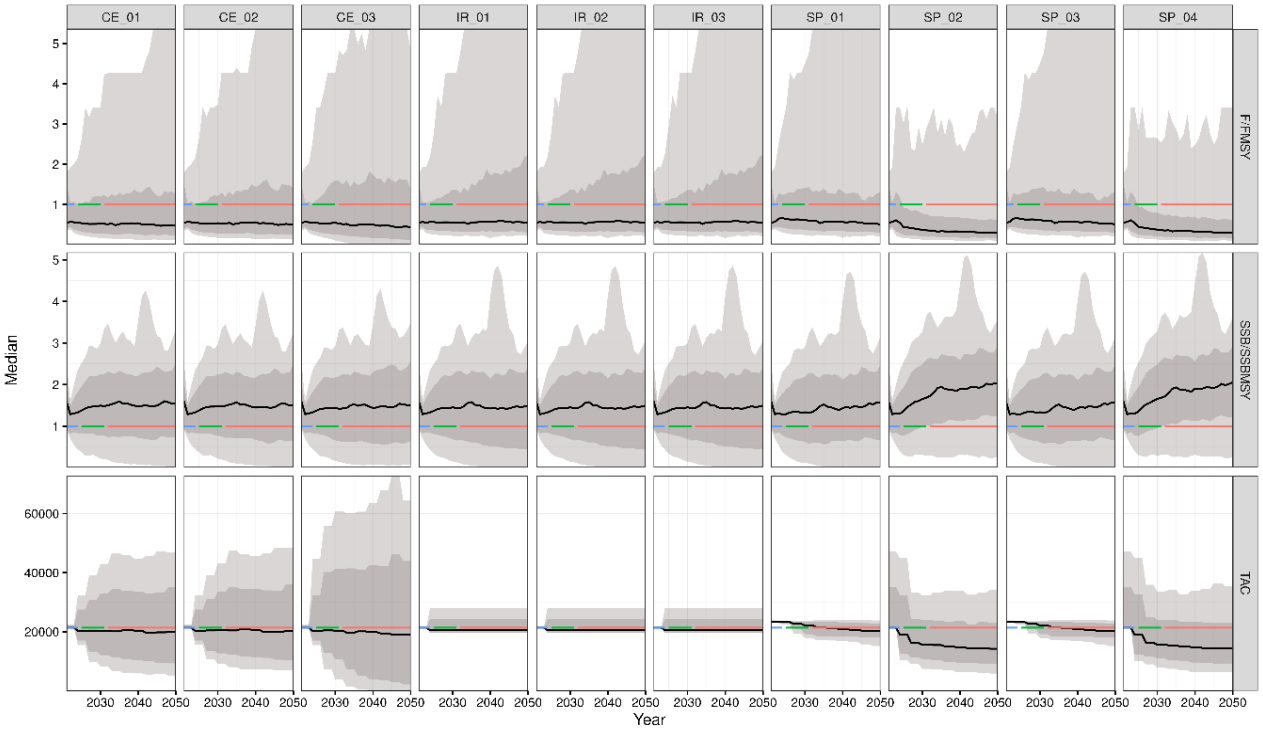


**Figure 3.** Trajectory of a) fishing mortality (F) relative to $F_{MSY}$ (top row), b) spawning stock biomass (SSB) relative to $SSB_{MSY}$ (middle row), and c) TAC (in tons, bottom row) for the PGK70% tunings of the 10 final CMPs. Results are summarized across all reference operating models. Blue bars show the short time period, while green depicts medium and red long.

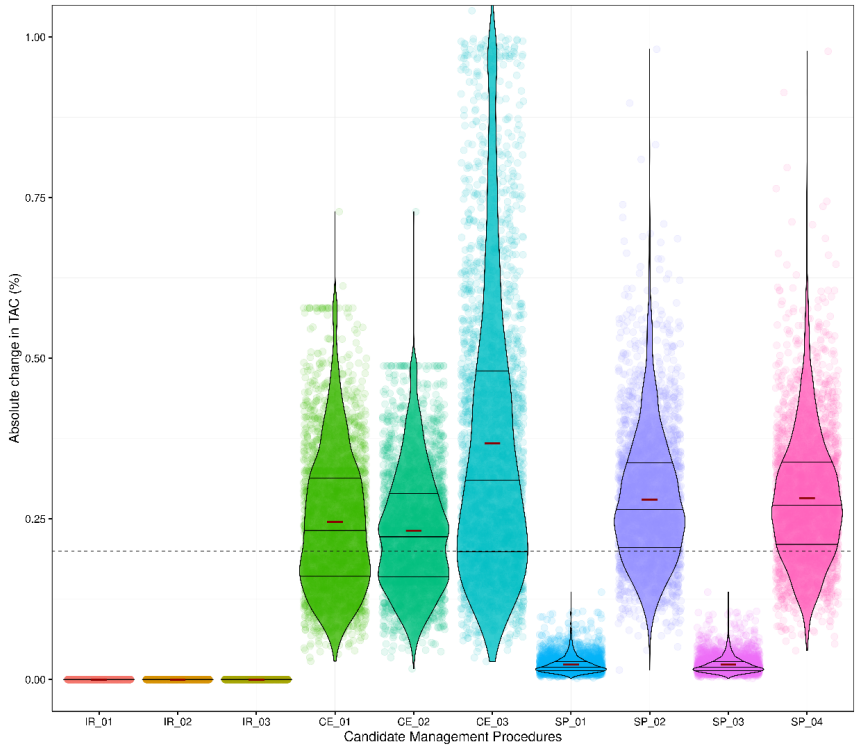


**Figure 4.** Violin plot for the change in TAC between management cycles. The width of the violin plot indicates the proportion of data points that are in each region of the plot (i.e., wide areas of the plot indicate a relatively large number of data points in that region, while narrow areas of the plot indicate few data points). The lines inside the violin plots indicate the 25, 50 and 75 percentiles, and the red line the mean of the distributions.

**Management objectives (from Res. 22-02 and the Panel 1 meetings in May 2023 and February 2024) and the current suite of corresponding performance indicators**

| *Management Objectives (Res. 22-02)* | *Proposed Corresponding Performance Indicators* |
|---|---|
| **Status**<br><br>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<br>**$PGK_{medium}$**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F < F_{MSY}$) in years 4-10<br>**$PGK_{long}$**: Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F < F_{MSY}$) over years 11-30<br>**$PGK_{all}$:** Probability of being in the Kobe green quadrant (i.e., $SSB \geq SSB_{MSY}$ and $F < F_{MSY}$) over years 1-30<br>**POF:** Probability of $F > F_{MSY}$ over years 1-30<br>**PNOF:** Probability of $F < F_{MSY}$ over years 1-30 |
| **Safety**<br><br>There should be no greater than 10% 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<br>**$LRP_{medium}$**: Probability of breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) over years 4-10<br>**$LRP_{long}$**: Probability of breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) over years 11-30<br>**$LRP_{all}$**: Probability of breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) over years 1-30<br>**$nLRP_{short}$**: Probability of not breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) over years 1-3<br>**$nLRP_{medium}$**: Probability of not breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) over years 4-10<br>**$nLRP_{long}$**: Probability of not breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) over years 11-30<br>**$nLRP_{all}$**: Probability of not breaching the limit reference point (i.e., $SSB < 0.4*SSB_{MSY}$) over years 1-30 |
| **Yield**<br><br>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<br>**$AvC_{medium}$** – Median catches (t) over years 4-10<br>**$AvC_{long}$** – Median catches (t) over years 11-30 |
| **Stability**<br><br>Any changes in TAC between management periods should be 20% or less[1]. | **$VarC_{medium}$** – Variation in TAC (%) between management cycles over years 4-10<br>**$VarC_{long}$** – Variation in TAC (%) between management cycles over years 11-30<br>**$Var_{all}$** – Variation in TAC (%) between management cycles over years 1-30 |

[1]CMPs should also be tested with no restriction on TAC changes from one management cycle to the next, as stated at the Panel 1 meetings in May 2023 and February 2024. 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**

## Draft schedule for MP implementation, assuming a 3-year management cycle

| | | *Activity* | | | | | *Data inputs* | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Management cycle** | **MP run** | **MP advice implemented** | **Stock assessment** | **MSE review** | **Exceptional circumstances** | **Combined index[1]** | **Exceptional circumstances indicators** |
| 2024 | | X | | | | | X | |
| 2025 | 1 | | X | | | X | | X |
| 2026 | | | | | | X | | X |
| 2027 | | X | | | | X | X | X |
| 2028 | 2 | | X | | | X | | X |
| 2029 | | | | | | X | | X |
| 2030 | | X | | X | X | X | X | X |

[1] The combined index may be updated every year, depending on the requirements set out in exceptional circumstances protocol (ECP).

## 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., Res. 22-02 for SKJ-W).

**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 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 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.