

North Atlantic Swordfish MSE: Final Results & Decision Guide

This document presents the final results of the North Atlantic swordfish management strategy evaluation (MSE). The intention is to facilitate discussions at the 8 October 2024 Panel 4 meeting and decision-making for adoption of a Management Procedure (MP) at the 24th Special Meeting of the Commission in November 2024.

2024 Updates

The SCRS Swordfish Species Group has made a number of updates and improvements to the North Atlantic swordfish Management Strategy Evaluation (MSE) in 2024. These include revising the combined index, reconditioning the operating models (OMs) based on updated catch data and indices, developing additional robustness OMs (for a total of 7 robustness OMs), and modifying the candidate management procedures (CMPs) to improve performance.

Management Objectives & Performance Indicators (PIs)

The N-SWO MSE includes 10 key performance indicators (PIs) as a benchmark for evaluation of the Commission's selected management objectives. **Appendix A** shows the current management objectives and performance indicators based on input received from Panel 4 in 2023.

Importantly, all yield performance indicators consider the Total Allowable Catch (TAC) to be landings plus dead discards.

Candidate Management Procedures

The SCRS Swordfish Species Group has worked collaboratively to develop and test a number of CMPs. Five CMPs remain, as agreed by Panel 4 in 2023. MCC9 and MCC11 are modified versions of the MCC CMPs developed in 2023, updated to include more steps to improve performance relative to the new combined index. The CE and SPSSFox CMPs remain unchanged. In addition to representing both model-based and empirical CMPs, the five remaining CMPs are SCRS-recommended because they cover a wide range of the performance tradeoff space, use a variety of TAC-setting rules, and because they use the combined index, which includes data from the broadest geographic and fleet coverage.

This table describes the CMP types:

	CE	MCC9	MCC11	SPSSFox	SPSSFox2
Type	Empirical	Empirical	Empirical	Model	Model
Index	Combined	Combined	Combined	Combined	Combined
Steps	N/A	9	11	N/A	N/A
Minimum TAC	N/A	4000 t	4609 t	N/A	N/A
Stability Limit (maximum allowed change between management cycles)	±25% cap	None	None	±25% cap	±25% cap, with no cap on TAC decreases if the MP's estimated $B < B_{MSY}$
Reference Period	2016-2020	2017-2019	2017-2019	N/A	N/A
Detailed Description	Attempts to maintain a constant exploitation rate in the projection period, based on the mean exploitation rate in the recent historical years.	Aims to maintain a mostly constant catch (MCC). The TAC is adjusted between a set of 9 steps based on the ratio of the mean index over the 3 most recent years compared to the mean index from 2017 – 2019.	Similar to MCC9 but the TAC is adjusted between a set of 11 steps and there is a different minimum TAC.	A Fox surplus production model with a hockey-stick HCR where fishing mortality decreases linearly from 100*BMSY to 40*BMSY.	Like SPSSFox but with a bifurcated stability restriction as described above in "Stability Limit"

Each of the 5 CMP types have b and c tuning variants. 'b-tuning' and 'c-tuning' CMPs are tuned to meet at least 60% or 70%, respectively, probability of being in the Kobe green quadrant for each decade across the 30-year projection period. There are therefore a total of ten final CMP variants.

The Safety minimum threshold requires that CMPs have greater than 85% probability of not breaching the limit reference point (LRP, i.e., $0.4 \cdot B_{MSY}$) at any point in the projection period. 90% and 95% probability options are also available. All CMPs achieve the Safety minimum threshold with 100% probability of not breaching the LRP. Performance against other management objectives is then compared.

CMPs use a 3-year management cycle and in testing, did not produce TAC changes of less than 200 t between management cycles. All CMPs use a two-year data lag, meaning that the TAC calculated for the first management cycle (2025-2027) uses data up to and including 2022.

Final CMP Performance Results

Included here are the key performance results for the ten final CMP variants. The full suite of results is available in the [online interactive application](#) (see, Other resources below).

Reference Operating Models (OMs)

For the Reference OMs, all CMPs had Probability of green Kobe (PGK) $\geq 60\%$ in the Short (2025-2034), Medium (2035-2044) and Long (2044-2054) time periods, and 100% probability of not breaching the limit reference point (LRP) (**Figures 1-4**).

The CE method had different behaviour compared to the other CMPs, with the lowest TAC in the Medium period and the highest spawning biomass at the end of the projection period (**Figures 1, 3 and 4**). CE also had the highest average variability in the TAC, with a mean of 18% and a maximum of 25%.

MCC9 and MCC11 had the lowest average variability in the TAC, with most TAC changes $< 20\%$ (**Figure 5**).

The SPSSFox and SPSSFox2 methods had almost identical performance across all performance indicators (**Figure 1 and Figure 5**).

Robustness Tests

Robustness OM 5, which evaluated a potential impact of Climate Change by simulating lower than expected recruitment deviations for first 15 years of projection period, was the most challenging test for the CMPs. In this scenario, the CE methods had the highest probability of breaching the LRP and resulted in a decline in the TAC throughout the projection period (**Figures B1-B3**).

SPSSFox2, which did not have a constraint on the change in TAC when the assessment model estimated the biomass to be below B_{MSY} , had the highest PGK and the lowest probability of overfishing (**Figures B1 and B2**). In response to the decline in the biomass early in the projection period, this CMP reduced the TAC to a lowest level of all the CMPs. The constraint of no more than a 25% increase in TAC prevented the TAC to increase quickly to higher levels once the biomass had rebuilt, and the biomass at the end of the projection period had rebuilt to over twice B_{MSY} while the TAC remained at relatively low levels (**Figures B2 and B3**).

	MP	AvTAC_long	AvTAC_med	AvTAC_short	nLRP	PGK	PGK_med	PGK_short	PNOF	VarC	TAC1
1	CE_b	11,820	8,266	14,172	1.00	0.79	0.87	0.60	0.83	0.18	14,172
2	CE_c	11,934	8,241	13,846	1.00	0.84	0.91	0.70	0.87	0.18	13,846
3	MCC9_b	12,258	11,315	14,144	1.00	0.73	0.78	0.60	0.80	0.12	15,087
4	MCC9_c	11,794	10,887	13,609	1.00	0.80	0.84	0.70	0.85	0.12	14,516
5	MCC11_b	11,911	10,958	14,769	1.00	0.71	0.74	0.60	0.78	0.12	14,769
6	MCC11_c	11,523	11,523	14,289	1.00	0.77	0.80	0.70	0.83	0.12	14,289
7	SPSSFox_b	11,557	11,397	13,869	1.00	0.73	0.75	0.60	0.79	0.14	15,629
8	SPSSFox_c	11,531	11,336	13,370	1.00	0.81	0.83	0.70	0.85	0.13	14,952
9	SPSSFox2_b	11,556	11,397	13,869	1.00	0.73	0.76	0.60	0.80	0.14	15,629
10	SPSSFox2_c	11,522	11,336	13,370	1.00	0.81	0.83	0.70	0.85	0.13	14,952

Figure 1. Quilt table showing results for the 5 remaining CMPs (each with two Status tuning options: PGK=60% - 'b', or 70% - 'c') against key performance indicators for the reference set of operating models. CMPs are listed in alphabetical order. See **Appendix A** for performance indicator descriptions. The nLRP performance indicator is the probability of not breaching the limit reference point; this modification of the LRP performance indicator means that higher values are better for all indicators except VarC. Darker shading indicates better performance, but some of the values are very similar, despite different shading.

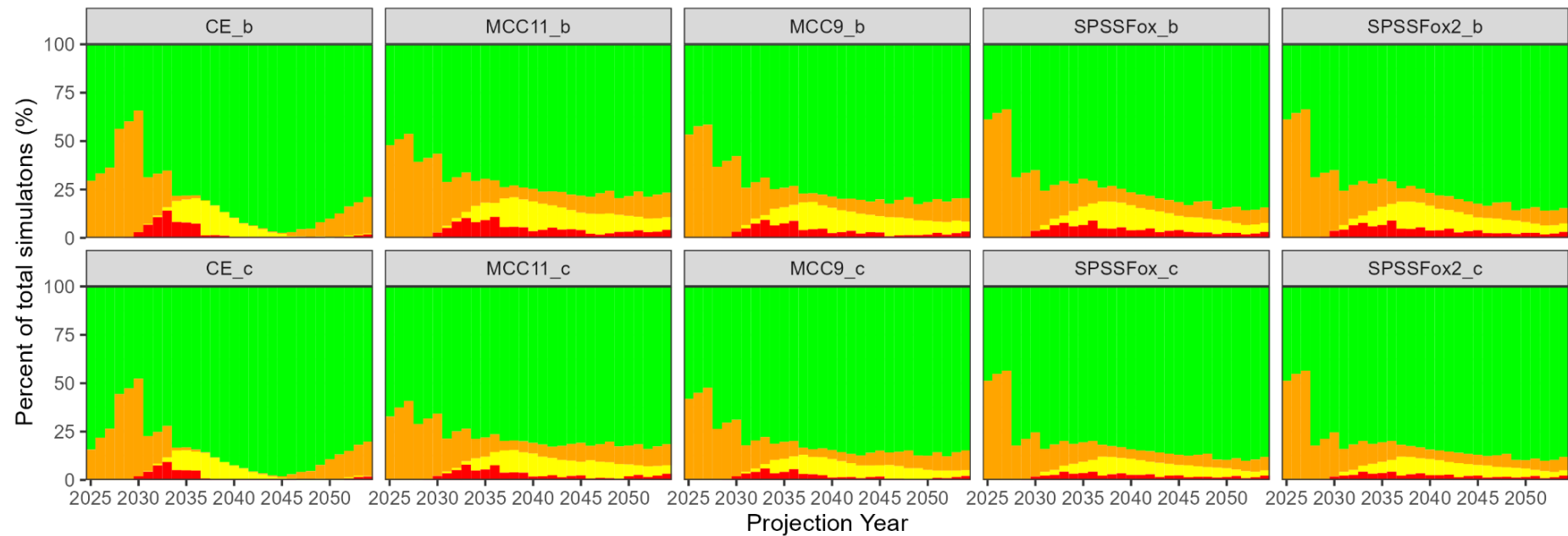


Figure 2. Kobe time plot showing the percentage (vertical axis) of simulations across all reference operating models that fall in each of the Kobe quadrants in each projection year (horizontal axis). Green indicates that the stock is neither overfished nor subject to overfishing. Orange means that the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

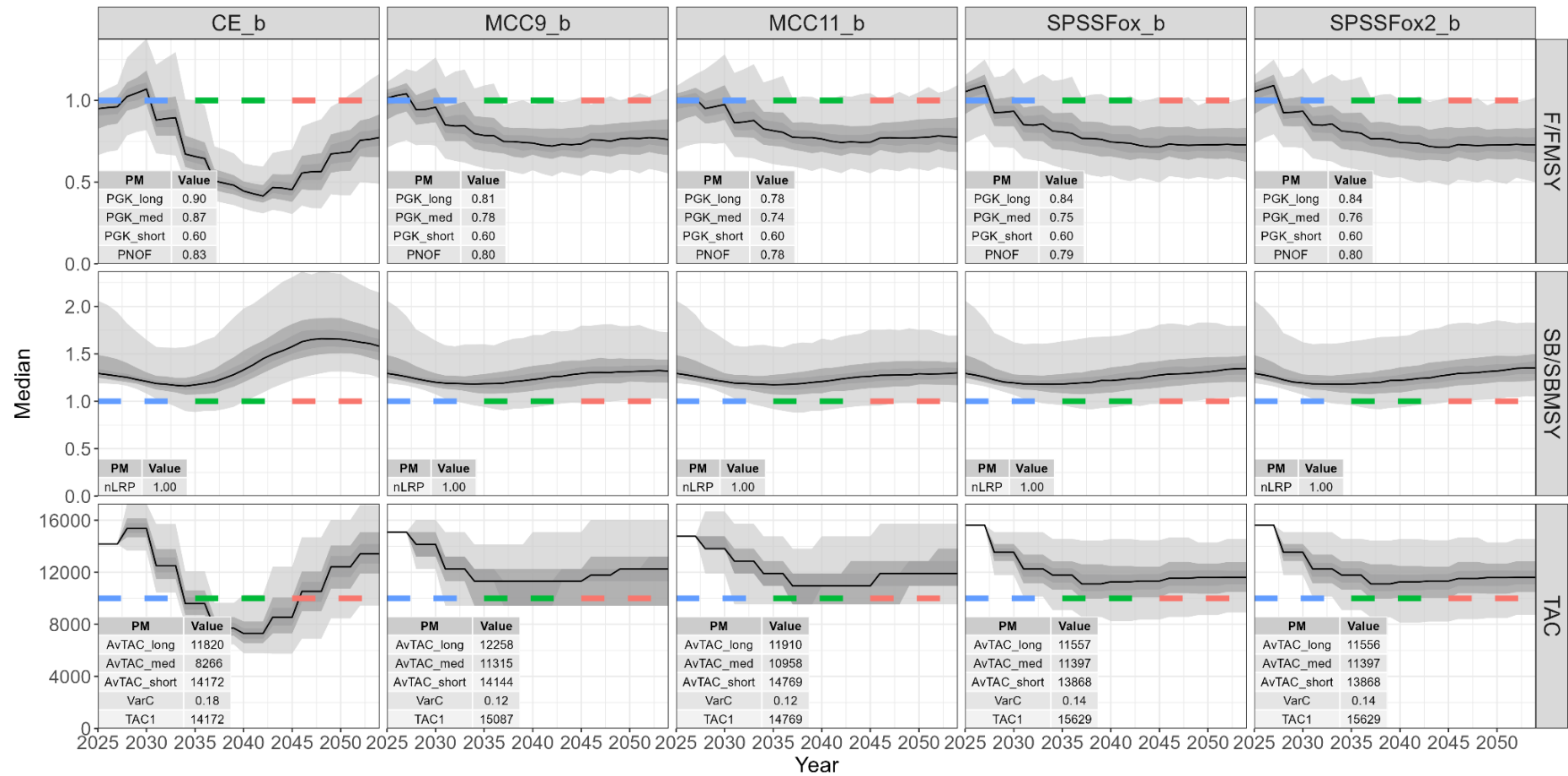


Figure 3. Trajectory of a) fishing mortality (F) relative to F_{MSY} (top row), b) spawning biomass (SB) relative to SB_{MSY} (middle row), and c) TAC (in tons, bottom row) for the 'b' tunings of the 5 final CMPs. Results are summarized across all reference operating models. Blue bars show the short time period, while green depicts medium and red long.

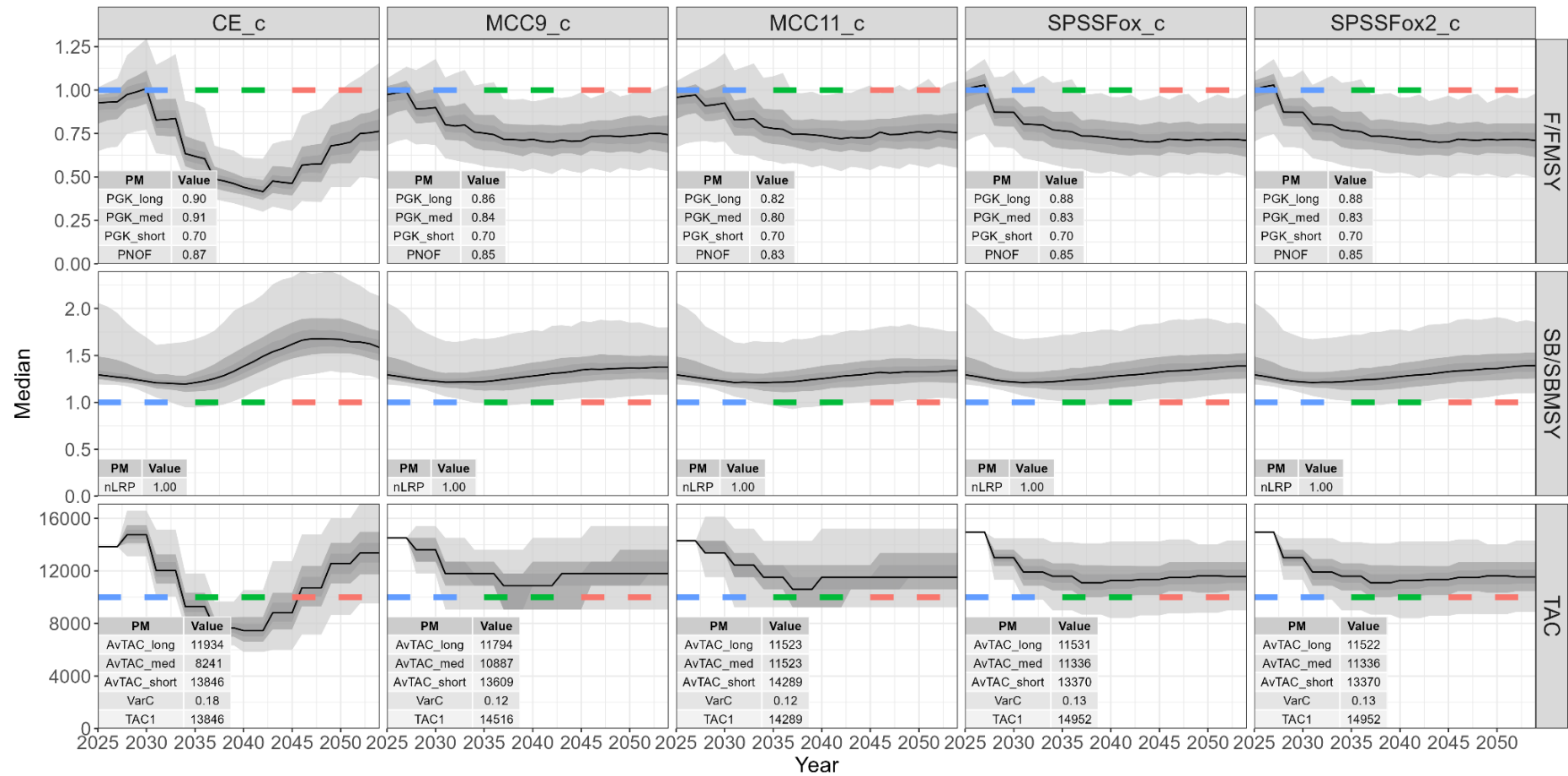


Figure 4. Trajectory of a) fishing mortality (F) relative to F_{MSY} (top row), b) spawning biomass (SB) relative to SB_{MSY} (middle row), and c) TAC (in tons, bottom row) for the 'c' tunings of the 5 final CMPs. Results are summarized across all reference operating models. Blue bars show the short time period, while green depicts medium and red long.

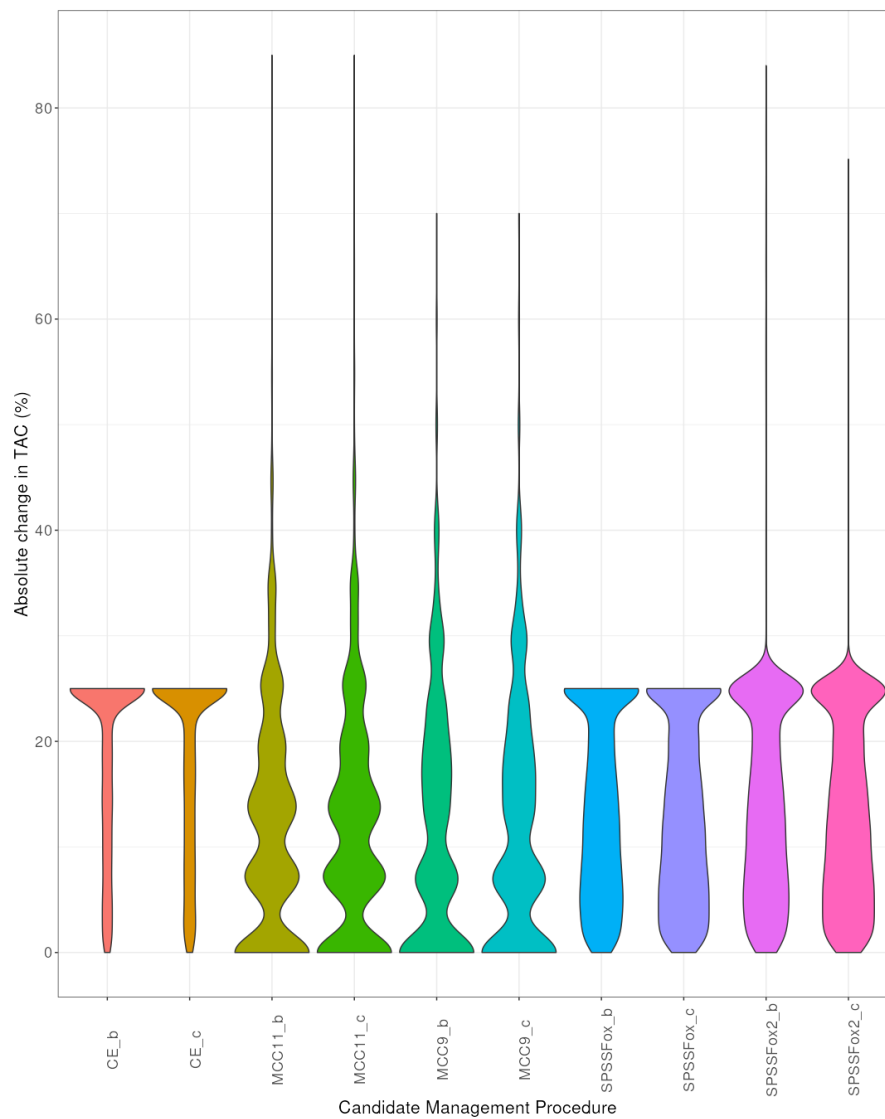


Figure 5. Violin plot for the change in TAC between management cycles. The width of the violin plot indicates the proportion of data points that are in each region of the plot (i.e., wide areas of the plot indicate a relatively large number of data points in that region, while narrow areas of the plot indicate few data points).

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 A), including:

- Minimum acceptable threshold for the Status objective. Options are 60% or 70% probability of occurring in the green quadrant of the Kobe matrix.
- Minimum acceptable threshold for the Safety objective. Options are 85%, 90% or 95% probability of the stock not falling below B_{LIM} ($0.4 \cdot B_{MSY}$) at any point during the 30-year evaluation period. These equate to a 15%, 10%, or 5% maximum probability, respectively, of breaching B_{LIM} , per the phrasing of the management objective.
 - Note that all CMPs in the short-list meet the most stringent safety objective threshold (95%), having a 100% chance of not falling below the limit reference point across the reference set of OMs.
- Maximum percent allowable change in TAC between management periods. Options are 25% (CE, SPSSFox), 25% with no limit on TAC decreases when the MP's estimated $B < B_{MSY}$ (SPSSFox2), or no limit (MCC9, MCC11).
- Results for CMP relative performance are provided above in **Figures 1-5** and may help to inform these decisions.

b) Final CMP type

- There are five remaining CMPs, each with two tunings ('b' and 'c') – CE, MCC9, MCC11, SPSSFox, and SPSSFox2.
- The 'b' CMP variants are tuned to 60% PGK for each decade over the 30-year projection period, while the 'c' CMP variants are tuned to 70% PGK.
- Each CMP uses the combined index.
- All CMPs meet the minimum operational objectives for Status and Safety but with varying performance on the Yield and Stability tradeoffs.
- The relative performance results are provided above in **Figures 1-5**. **Appendix B** contains CMP results for robustness scenario R5 (climate change effects on recruitment, called 'R3b in 2023). Because performance for all CMPs is strong for the reference set of OMs, Panel 4 may wish to pay close attention to the more challenging robustness OMs, like R5.

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 C** for Panel 4'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

[North Atlantic Swordfish MSE splash page](#)

[North Atlantic Swordfish MSE interactive Shiny App](#) (includes final results)

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

Appendix A

Current management objectives and corresponding performance indicators based on input received at the Panel 4 meetings in 2023. Importantly, all yield performance indicators calculate the TAC as landings plus dead discards. Bracketed text notes remaining decision points.

<i>Management objectives</i>	<i>Corresponding key performance indicators</i>
Status The stock should have a [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., $SB \geq SB_{MSY}$ and $F < F_{MSY}$) in years 1-10 PGK_{MED} : Probability of being in the Kobe green quadrant (i.e., $SB \geq SB_{MSY}$ and $F < F_{MSY}$) in years 11-20 PGK_{ALL} : Probability of being in the Kobe green quadrant (i.e., $SB \geq SB_{MSY}$ and $F < F_{MSY}$) 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} ($0.4 * SB_{MSY}$) at any point during the 30-year evaluation period.	LRP_{ALL}¹ : Probability of breaching the limit reference point (i.e., $SB < 0.4 * SB_{MSY}$) in any of years 1-30.
Yield Maximize overall catch levels.	TAC₁ : TAC in the first management cycle (2025-27) 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 and bifurcated stability when $SB < SB_{MSY}$.]	VarC : Mean variation in TAC (%) between management cycles over years 1-30

¹ nLRP (not breaching the LRP) is used when it is more appropriate for higher values of performance indicators to indicate a 'safer' outcome, such as in trade-off plots. For example, a 15% LRP threshold is equivalent to a nLRP threshold of 85%.

CMP results for Robustness Scenario R5 – Climate Change effects on recruitment

	MP	AvTAC_long	AvTAC_med	AvTAC_short	nLRP	PGK	PGK_med	PGK_short	PNOF	VarC	TAC1
1	CE_b	3,244	6,457	14,172	0.30	0.17	0.01	0.06	0.39	0.23	14,172
2	CE_c	3,411	6,266	13,846	0.39	0.23	0.01	0.11	0.48	0.22	13,846
3	MCC9_b	9,429	7,072	14,144	0.39	0.13	0.00	0.01	0.47	0.22	15,087
4	MCC9_c	9,072	6,804	13,609	0.51	0.16	0.00	0.04	0.50	0.20	14,516
5	MCC11_b	7,146	7,146	14,769	0.34	0.10	0.00	0.02	0.44	0.19	14,769
6	MCC11_c	9,219	6,914	14,289	0.46	0.15	0.00	0.07	0.48	0.19	14,289
7	SPSSFox_b	4,327	6,426	13,668	0.40	0.21	0.00	0.00	0.49	0.21	15,629
8	SPSSFox_c	5,001	6,482	13,146	0.58	0.24	0.00	0.03	0.53	0.21	14,952
9	SPSSFox2_b	2,977	2,544	13,668	0.64	0.35	0.08	0.00	0.63	0.29	15,629
10	SPSSFox2_c	3,493	3,201	13,146	0.78	0.35	0.07	0.03	0.62	0.27	14,952

Figure B1. Quilt table showing results for the 5 remaining CMPs (each with two Status tuning options: PGK=60% - 'b', or 70% - 'c') against key performance indicators for robustness operating model 5 (climate change effects on recruitment). CMPs are listed in alphabetical order. See **Appendix A** for performance indicator descriptions. The nLRP performance indicator is the probability of not breaching the limit reference point; this modification of the LRP performance indicator means that higher values are better for all indicators except VarC. Darker shading indicates better performance, but some of the values are very similar, despite different shading.

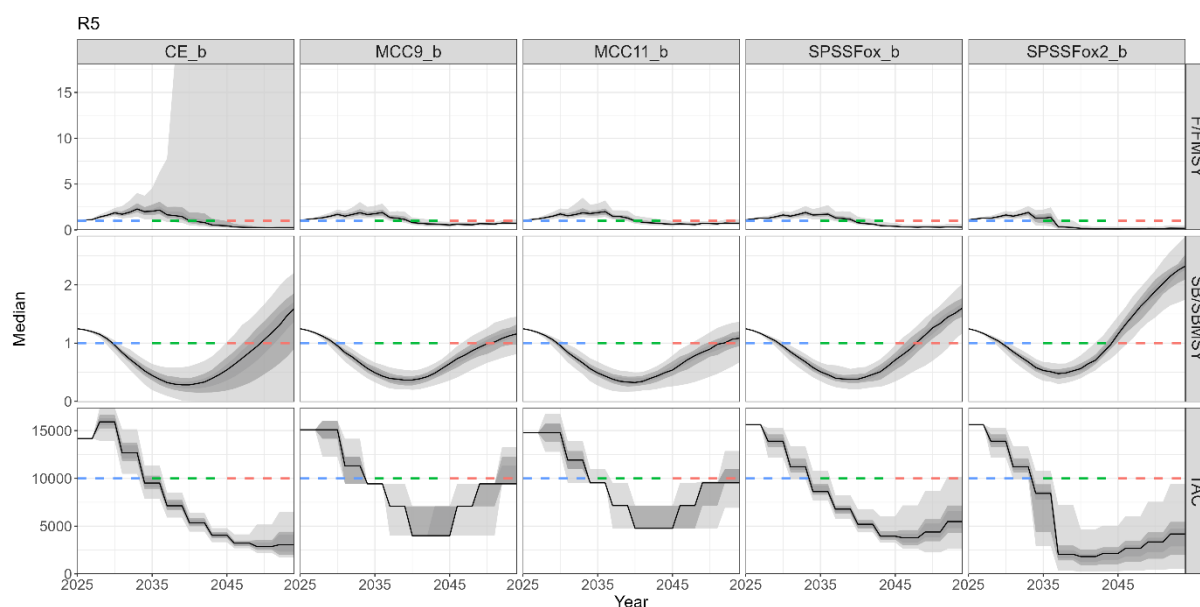


Figure B2. Trajectory of fishing mortality (F) relative to F_{MSY} (top), spawning biomass (SB) relative to SB_{MSY} (middle) and the TAC for 'b' tunings of the CMPs under the Climate Change robustness test R5 (features a decline in recruitment in the first fifteen years, followed by a return to average recruitment for the remainder of the projection period). The dark black trend line shows the median value of SB, while the increasingly lighter shades of grey show the 50th, 60th, and 90th percentiles, respectively. The coloured horizontal line shows the SB_{MSY} target over the short (blue), medium (green) and long (red) terms.

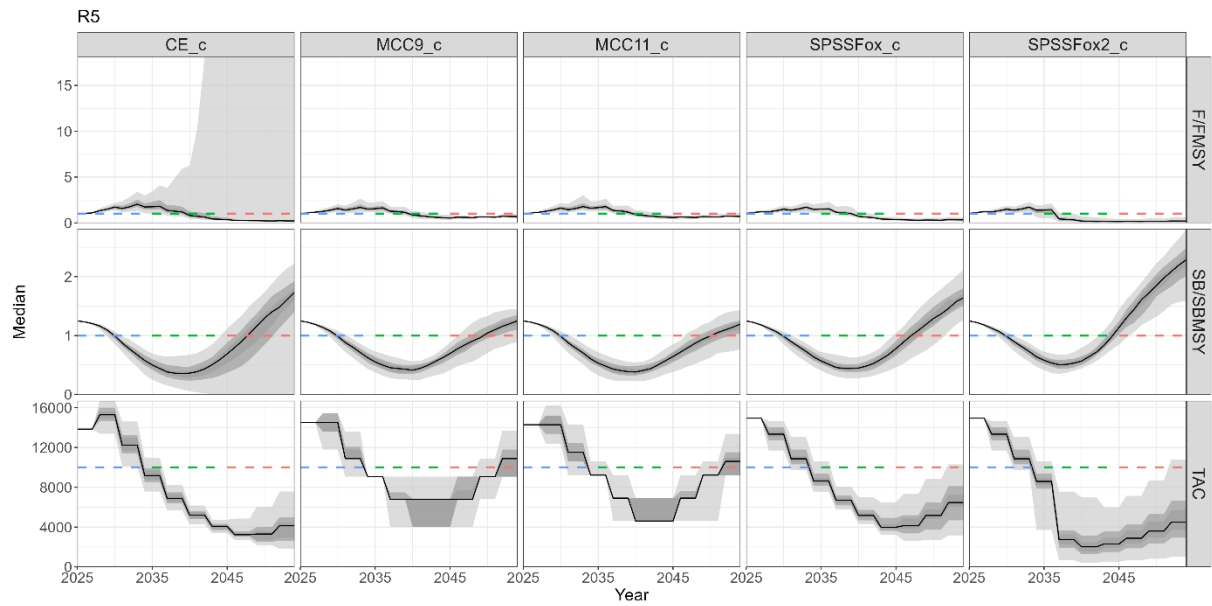


Figure B3. Trajectory of fishing mortality (F) relative to F_{MSY} (top), spawning biomass (SB) relative to SB_{MSY} (middle) and the TAC for 'c' tunings of the CMPs under the Climate Change robustness test R5 (features a decline in recruitment in the first fifteen years, followed by a return to average recruitment for the remainder of the projection period). The dark black trend line shows the median value of SB , while the increasingly lighter shades of grey show the 50th, 60th, and 90th percentiles, respectively. The coloured horizontal line shows the SB_{MSY} target over the short (blue), medium (green) and long (red) terms.

Appendix C

Proposed schedule for data provision, updating MPs, evaluating for exceptional circumstances (EC), stock assessments, and MP/MSE review

		<i>Activity</i>					<i>Data inputs</i>	
Year	Management cycle	MP run	MP advice implemented	Stock assessment	MSE Review	Exceptional circumstances evaluated	Combined index ²	Exceptional circumstance indicators
2024		x					x	
2025	1		x			x		x
2026						x		x
2027		x				x	x	x
2028	2		x	[x]		x		x
2029				[x]		x		x
2030		x			[x]	x	x	x
2031	3		x			x		x
2032						x		x
2033		x				x	x	x

² The combined index may be updated every year, depending on the requirements set out in the exceptional circumstances protocol (ECP).