Appendix 20

Candidate Management Procedures (CMP) results for North Atlantic swordfish management strategy evaluation (SWO-N MSE)

Introduction

The Commission is scheduled to adopt a management procedure (MP) for North Atlantic swordfish in 2023. To support the Commission in this decision making, the Committee has prepared several documents, a webpage, and an interactive online platform (SWO-N Shiny App) which present the final reporting of CMP performance and trade-offs relative to predetermined performance metrics. A Trial Specification Document provides a detailed description of technical elements for this MSE. This appendix provides a brief description of CMP results.

Methods

Operating models

Operating models for the SWO-N MSE were based on the 2022 Stock Assessment (Anon., 2022c), conducted with the Stock Synthesis 3 (SS3) assessment software. The operating models (OMs) were classified into two categories: the Reference Set, which spanned the key uncertainties in the 2022 stock assessment, and the Robustness OMs, a subset of the Reference Set that were modified to account for additional potential uncertainties.

Reference Operating Models

Natural mortality rate (M) and the steepness of the Beverton-Holt stock-recruit relationship (h) are the axes of uncertainty included in the reference set of operating models. Three values were selected for each parameter (M=0.1, 0.2, 0.3 and h=0.69, 0.80, 0.88), and nine operating models were conditioned with these assumed values. One OM of the Reference Set (M=0.2 & h=0.88) shared identical assumptions with the 2022 Stock Assessment.

Robustness tests

A set of Robustness OMs were developed to evaluate the impact of additional uncertainties that were not considered in the Reference Set. Five Robustness OMs were developed to consider additional uncertainties for the historical and projection periods. **Table 1** provides a summary of the Robustness OMs.

Management cycle testing

All CMPs are designed with a three-year management cycle. For a subset of CMPs, a four-year management cycle was tested and performance compared to the three-year versions.

Minimum TAC threshold testing

A subset of CMPs were tested for performance under a scenario where Total Allowable Catch (TAC) was not changed between management cycles if the CMP recommended a change in TAC of less than 200 t.

Performance Metrics

Panel 4 identified 10 performance metrics as primary criteria for comparing performance of CMPs (**Table 2**).

Candidate Management Procedures

A large number of CMPs were developed by the Committee and then reduced to a shortlist using a culling procedure approved by Panel 4. Five CMP types, each tuned to three tuning targets (51%, 60%, and 70% probability of being in the green quadrant of the Kobe plot in the short time period, years 1-10) were identified for inclusion on the shortlist. For each CMP type, where "a" script is added to the CMP name (e.g., "CE_a") the CMP was tuned to achieve 51% probability of being in the green zone of the Kobe plot in the short time period (years 1-10). The "b" and "c" scripts indicate that the CMP was tuned to achieve 60%, or 70% probability, respectively, of being in the green zone of the Kobe plot, Probability of Green Kobe (PGK), in the short time period (years 1-10). A description of each of these CMPs is found in **Table 3**.

Results and Discussion

Table 4 shows the performance of CMPs relative to the 10 performance metrics identified by Panel 4. For each of the CMPs a time series for fishing mortality, biomass, and TAC trends in the projections were plotted (an example time series plot for the CE_b is shown in **Figure 1**).

Given the structural differences in the CMPs, their performance differs across metrics. Trade-offs between the CMPs are shown in **Figure 2** for the OM reference set. This figure shows trade-offs in PGK against average TAC, the probability of not breaching the limit reference point (LRP) against average TAC, and the mean variation in TAC (shown as a negative value so lower values mean more variable) against TAC. Robustness tests in SWO MSE include scenarios that are often more challenging for the CMPs. **Figure 3** shows the same set of trade-offs as described above, but for Robustness scenario 3b.

Variability in TAC between management periods among the CMPs is shown in a violin plot (**Figure 4**). As per Panel 4's request, the Committee tested CMPs with and without limits in maximum change in TAC between management cycles. **Figure 4** shows the distribution of the absolute change in TAC for the CMPs. The width of the violin plot is proportional to the frequency of the absolute change in TAC (i.e., wider areas mean value is more common).

All short-listed CMPs achieved the minimum requirements for performance identified by Panel 4. Notably, all short-listed CMPs have a very high probability of not breaching the 0.4 B_{MSY} LRP (**Table 4**). In all cases CMPs achieved >95% probability of not breaching LRP in the entire projection period, and in most cases >98% probability of not breaching LRP in the entire projection period. The minimum acceptable probability for not breaching the LRP identified by Panel 4 is 85%.

In addition to the core list of Robustness scenarios, the Committee examined a scenario where management cycle length was four years instead of three (**Table 5**). The results showed the 4-year management cycles had only a small impact on the performance CMPs compared to the 3-year interval. The Committee also examined a scenario where TAC was not changed between management cycles if the CMP recommended a change in TAC less than 200 t (**Table 6**). The results showed the minimum TAC change of 200 t had no impact on the performance of the CMPs, as the change in TAC between management cycles was always greater than 200 t.

These results provide information that the Committee anticipates will support the Commission in selection of a MP for management of the North Atlantic swordfish stock.

Table 1. Description of the Robustness operating models (OMs) developed for the North Atlantic swordfish MSE.

Robustness OM	***Purpose***
R0	Reference OM for the Robustness tests.
R1	Evaluate impact of an assumed 1 percent annual increase in catchability that is not accounted for in the standardization of the indices of abundance (historical & projection)
R2	Same as R2, but only for the historical period
R3a	Evaluate impact of cyclical pattern in recruitment deviations in the projection period; a proxy for impact of climate change on stock productivity
R3b	Evaluate impact of lower than expected recruitment deviations for first 15 years of projection period; a proxy for impact of Climate Change on stock productivity
R4	Evaluate impact of illegal, unreported, or unregulated catches. A 10% overage in TAC each year.

Table 2. Summary of the Management Objectives and corresponding Performance Metrics (PMs) developed for the North Atlantic swordfish MSE.

Category	***Management Objective***	***PM Name***	***PM Description***
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 Green Zone of Kobe Space ($SB>SB_{MSY}$ & $F<F_{MSY}$) in years 1-10 (2024-2033)
		PGK_{med}	Probability of being in Green Zone of Kobe Space ($SB>SB_{MSY}$ & $F<F_{MSY}$) in years 11-20 (2034-2043)
		PGK_{long}	Probability of being in Green Zone of Kobe Space ($SB>SB_{MSY}$ & $F<F_{MSY}$) in years 21-30 (2044-2053)
		PGK	Probability of being in Green Zone of Kobe Space ($SB>SB_{MSY}$ & $F<F_{MSY}$) over all years (2024-2053)
		PNOF	Probability of Not Overfishing ($F<F_{MSY}$) over all years (2024-2053)
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	Probability of breaching the limit reference point ($SB<0.4SB_{MSY}$) in any year (2024-2053)
Yield	Maximize overall catch levels.	TAC1	TAC (t) in the first implementation year (2024)
		$AvTAC_{short}$	Median TAC (t) over years 1-10 (2024-2033)
		$AvTAC_{med}$	Median TAC (t) over years 11-20 (2034-2043)
		$AvTAC_{long}$	Median TAC (t) over years 21-30 (2044-2053)
Stability	Any increase or decrease in TAC between management periods should be less than [25]%. [also test no stability limitation]	VarC	Mean variation in TAC (%) between management cycles over all years and simulations

Table 3. Summary of the shortlisted candidate management procedures that were developed and tested for the North Atlantic swordfish MSE.

Name	***Type***	***Abundance Indicator***	***Description***
CE	Empirical	Combined index	Attempts to maintain a constant exploitation rate in the projection period, based on the mean exploitation rate in the recent historical years.
MCC5	Empirical	Combined index	Mostly Constant Catch 5 (MCC) focuses on trying to provide a stable TAC. To do this it uses a base TAC which has the possibility of increasing by one step and decreasing by 2 steps. These steps are selected depending on the value of the current 3-yr average of the Combined Index compared to a 3-yr historical average (2017-2019). The minimum TAC set at 4kt when the current 3-yr average of the Combine Index is less than half of the 3-yr historical average.
MCC7	Empirical	Combined index	Mostly Constant Catch 7 (MCC) focuses on trying to provide a stable TAC. To do this it uses a base TAC which has the possibility of increasing by four small steps and decreasing by 2 steps. These steps are selected depending on a value of the current 3-yr average of the Combined Index compared to a 3-yr historical average (2017-2019). The minimum TAC is set at 50% of the base TAC when the current 3-yr average of the Combine Index is less than half of the 3-yr historical average. When the 3-yr average of the combined Index is calculated, a smoother is used to reduce its variability year-to-year.
SPSSFox	Model	Combined index	A Fox surplus production model with a harvest control rule that throttles F when estimated biomass is below target level.
FX4	Empirical	Combined index	The combined index is subjected to a median smoother of length 3 and then the deciles of the smoothed index are compared with the average of the most recent 3 years of data in order to find the appropriate percentile interval and associated percent TAC change. The percent TAC change adjusts a base TAC which varies according to the PGK_short tuning objective.

Table 4: Quilt table indicating performance metric values for each of the short listed CMPs. An interactive version of this table is available in the SWO-N MSE Shiny Application. This table shows 12 CMP configurations (rows) and 10 performance metrics (columns). The selection of the CMPs and performance metrics can be customized in the Shiny application. The cells are shaded indicating the range of values, with darker colors indicating more desirable outcomes for the various performance metrics. In this table TAC1 is estimated from the OMs. The final value for TAC1 will be calculated using the update to the combined index.

	MP	AvTAC_long	AvTAC_med	AvTAC_short	nLRP	PGK	PGK_med	PGK_short	PNOF	TAC1	VarC
	All	All	All	All	All	All	All	All	All	All	All
1	CE_a	11655.14	11387.05	13446.71	0.96	0.53	0.51	0.51	0.68	13462.5	0.16
2	CE_b	11651.06	11292.16	12768.65	0.97	0.61	0.59	0.6	0.74	12858.27	0.15
3	CE_c	11555.8	11218.02	12158	0.98	0.69	0.68	0.7	0.79	12247.38	0.15
4	FX4_b	12324.66	12632.78	12940.89	0.99	0.6	0.57	0.6	0.71	12940.89	0.1
5	FX4_c	12084.33	12379.07	12379.07	1	0.71	0.7	0.7	0.82	12379.07	0.1
6	MCC5_b	11188.4	11188.4	13426.08	0.99	0.58	0.56	0.6	0.68	13426.08	0.06
7	MCC5_c	12854.07	12854.07	12854.07	1	0.7	0.68	0.7	0.8	12854.07	0.06
8	MCC7_b	11564.15	11564.15	13141.08	1	0.59	0.57	0.6	0.71	13141.08	0.09
9	MCC7_c	12505.21	12005	12505.21	1	0.7	0.69	0.7	0.81	12505.21	0.09
10	SPSSFox_a	11792.19	11819.34	13462.5	0.97	0.53	0.51	0.51	0.67	13462.5	0.17
11	SPSSFox_b	11680.82	11603.5	12753.58	0.99	0.63	0.62	0.6	0.75	13292.91	0.16
12	SPSSFox_c	11571.51	11473.42	12189.85	1	0.72	0.7	0.7	0.82	12521.77	0.15

Table 5. Results for testing of an alternative management cycle length. CMPs CE, FX4, and MCC7 were tested with a 4-year management cycle and compared to the default where the management interval was every 3-years.

MP	*Interval*	*PGK*	*Mean Landings*	*VarC*
CE	3	0.43	10955	0.18
CE	4	0.44	11074	0.18
FX4	3	0.56	11027	0.09
FX4	4	0.56	11020	0.11
MCC7	3	0.47	11226	0.1
MCC7	4	0.47	11199	0.12

Table 6. CMPs CE, FX4, and MCC7 were tested with a minimum TAC change of 200 t and compared to the default where there was no minimum value for the TAC adjustment.

CMP	*Minimum TAC Change*	*PGK*	*Mean landings*	*VarC*
CE	None	0.43	10955	0.18
CE	200 t	0.43	10955	0.18
FX4	None	0.56	11027	0.09
FX4	200 t	0.56	11027	0.09
MCC7	None	0.47	11226	0.1
MCC7	200 t	0.47	11226	0.1

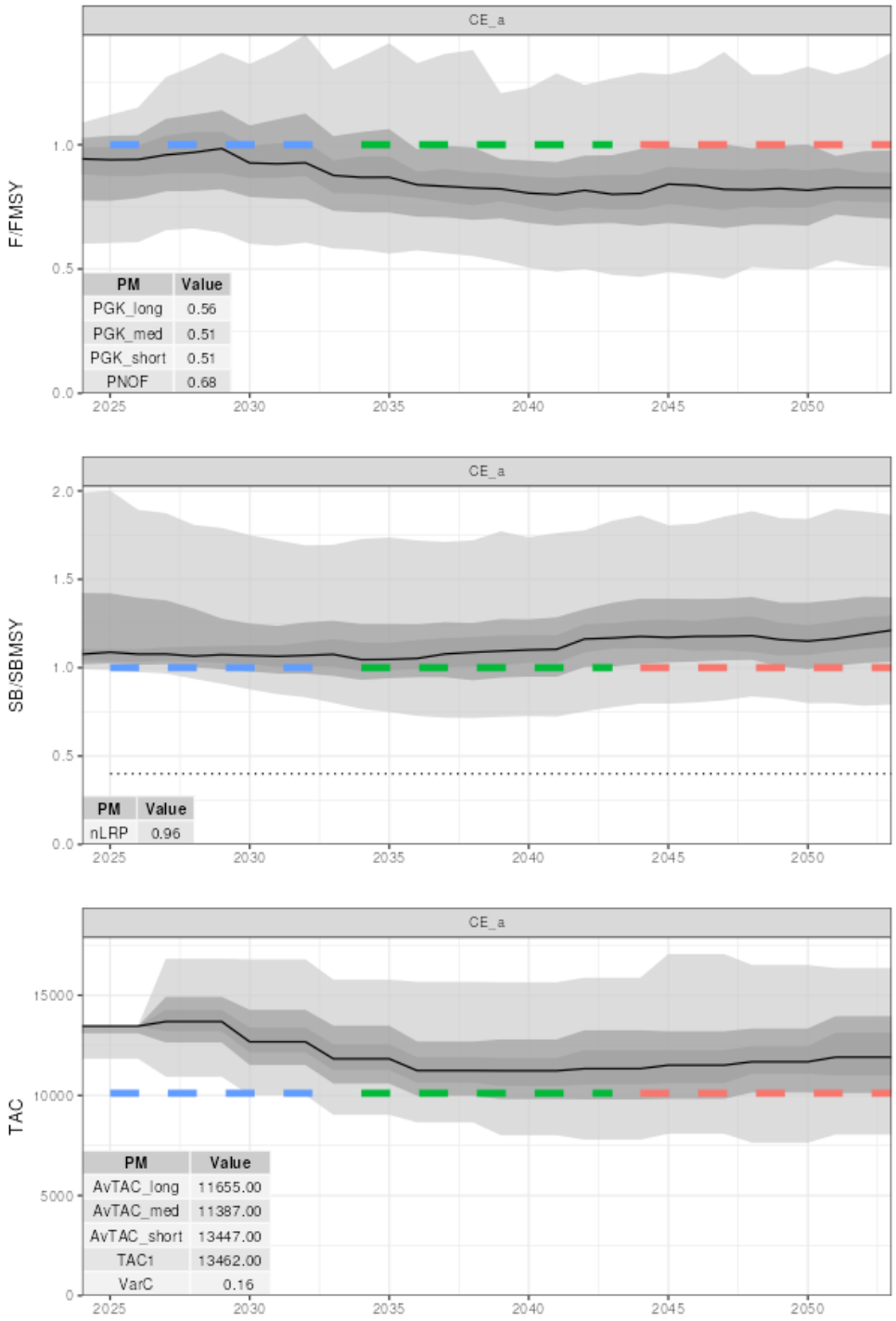

Figure 1. Time-series plots for one configuration of one of the CMPs (CE_a), showing the median (black line), 60th, 70th, and 90th percentiles (increasingly lighter shades of grey respectively) for F/F_{MSY} (top), SB/SB_{MSY} (center), and the TAC (bottom) over the 30-year projection period. This plot shows results for the nine reference operating models. Other plots are available for the Robustness models in the Shiny application. The performance metrics associated with this configuration of the CE_a CMP are shown in tables in the bottom left of each plot. The coloured dashed lines indicate the short (blue), medium (red), and long (green) time spans used in the performance metrics.

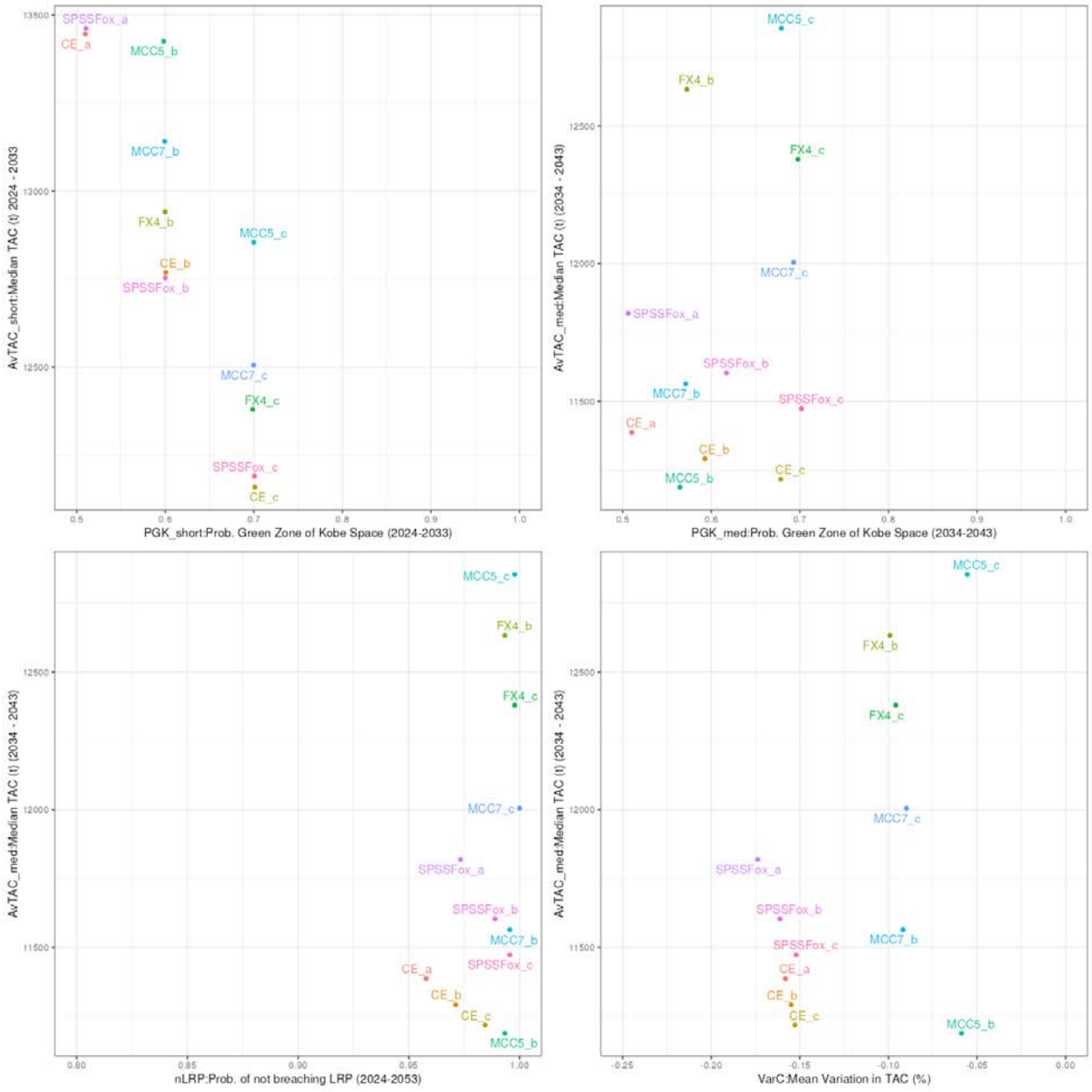

Figure 2. An example of a set of trade-off plots showing the results from 12 configurations of 5 CMPs for the Reference operating models. The plots show the trade-offs between the probability of being in the green space of the Kobe matrix (PGK) in the first 10-years of the projection period against the average TAC over this same period (top left), the PGK in years 11 – 20 against the average TAC over this same period (top right), the probability of not breaching the limit reference point against the average TAC in years 11 – 20 (bottom left), and the mean variation in TAC (shown as a negative value so lower values mean more variable) against the median TAC in the medium timeframe (bottom right).

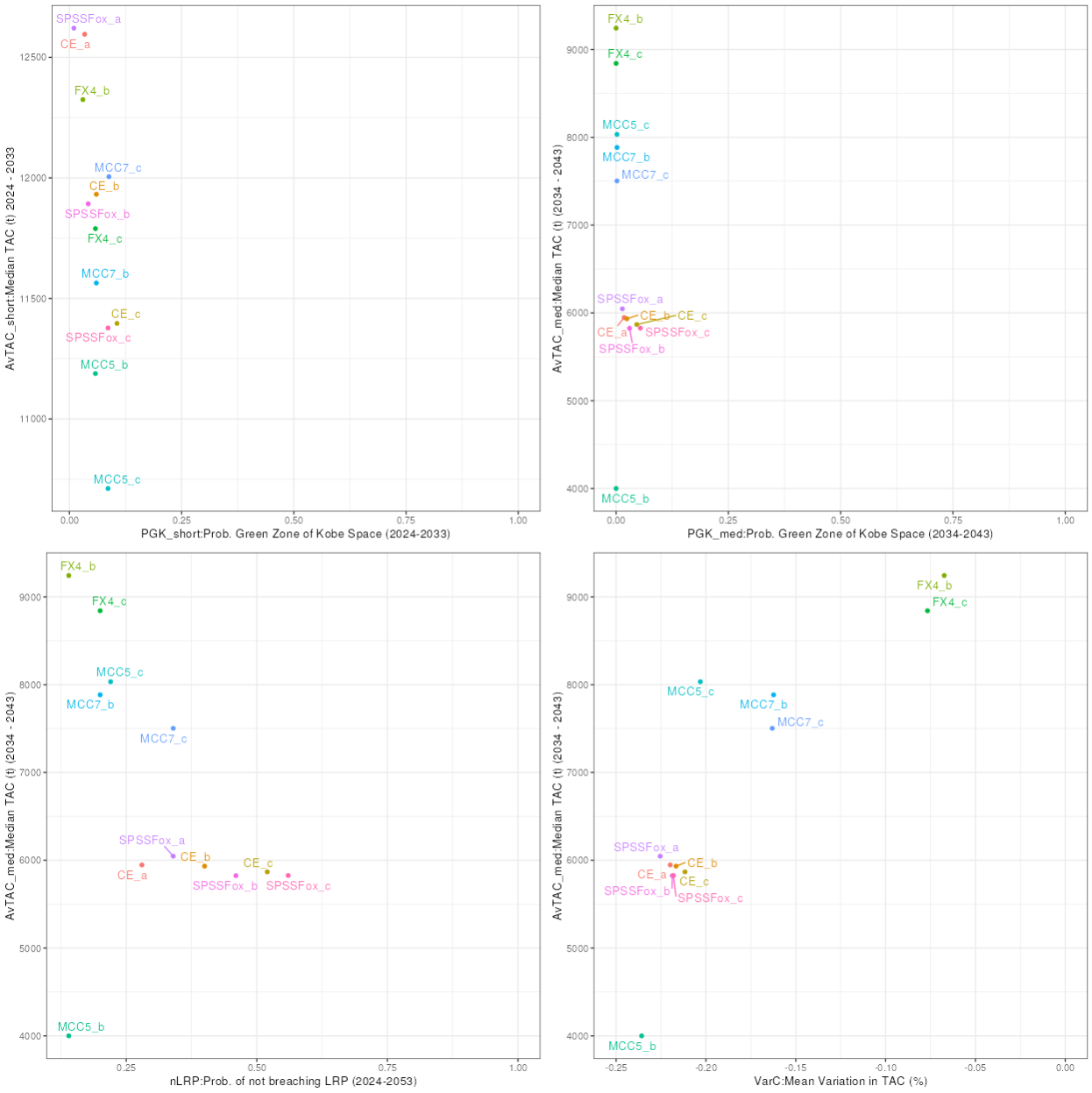

Figure 3. An example of a set of trade-off plots showing the results from 12 configurations of 5 CMPs for the Robustness operating model 3b (Climate Change). The plots show the trade-offs between the probability of being in the green space of the Kobe matrix (PGK) in the first 10-years of the projection period against the average TAC over this same period (top left), the PGK in years 11-20 against the average TAC over this same period (top right), the probability of not breaching the limit reference point against the average TAC in years 11-20 (bottom left), and the mean variation in TAC (shown as a negative value so lower values mean more variable) against the median TAC in the medium timeframe (bottom right).

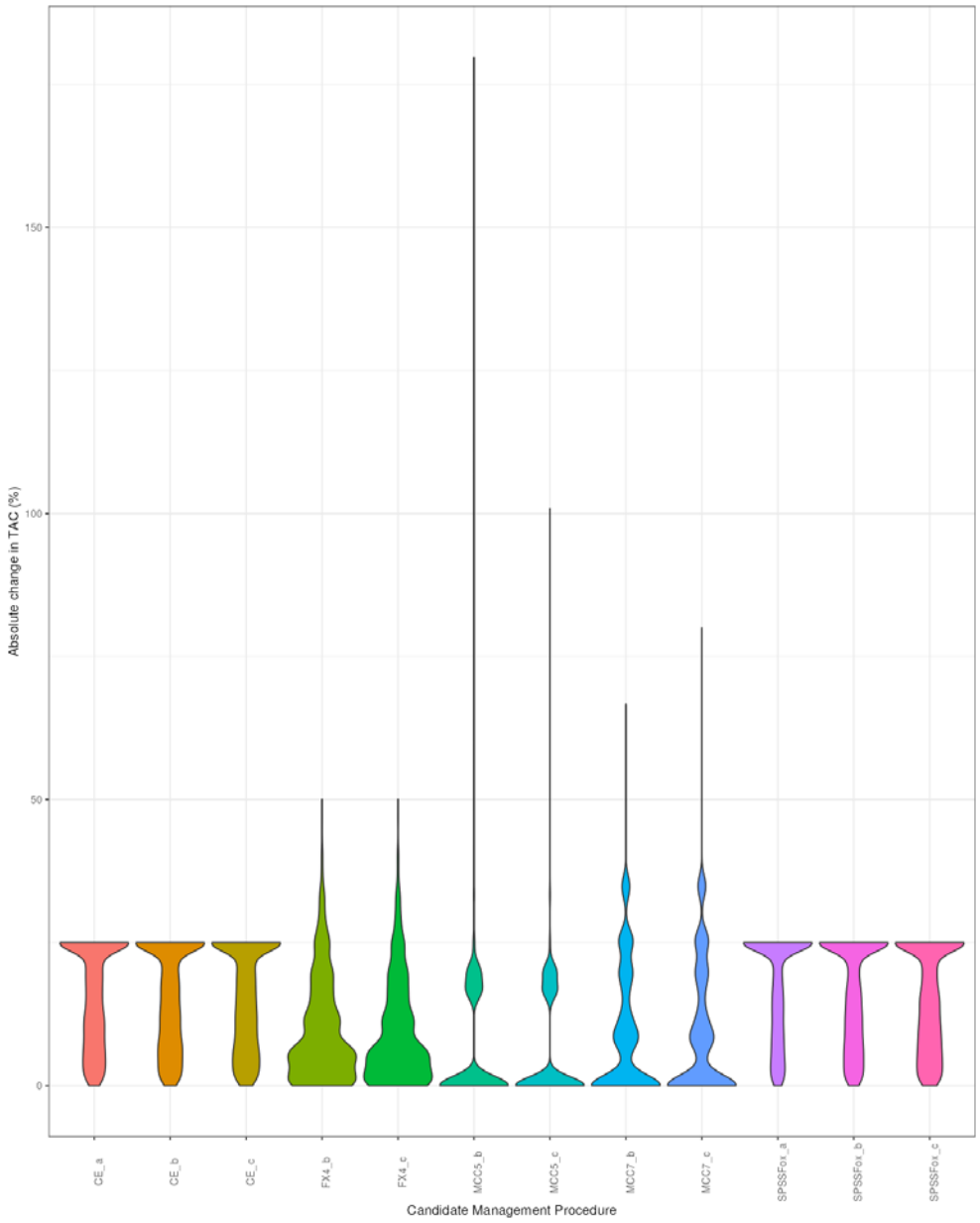

Figure 4. An example of a violin plot showing the distribution of the absolute change in TAC (y-axis) for five CMP configurations (x-axis). The width of the violin plot is proportional to the frequency of the absolute change in TAC (i.e., wider areas mean value is more common).