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Evaluation of candidate management procedures for South Pacific albacore

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F. Scott[1], R. Scott, N. Yao, P. Hamer, and G.M. Pilling

REVISIONS

- Catches in the operating models have been updated to use the most recently available data. Only the y-axis on the catch plots has changed as a result. All other results remain the same.

[1] Oceanic Fisheries Programme, The Pacific Community

Executive Summary

Revisions:

- Catches in the operating models have been updated to use most recently available data. Only the y-axis on the catch plots have changed as a result. All other results remain the same.

This report describes the updated MSE framework for South Pacific albacore, as well as the preliminary results from several candidate management procedures (MPs).

Candidate MPs are developed based on four harvest control rule (HCR) shapes, combined with different levels of constraint on how much the HCR output can change between management periods, consistent with candidate MPs that have been shown before. Only troll and longline fisheries operating in the WCPFC-CA are managed through the MP, through the setting of catch limits. The HCR baseline is the average catch level in the period 2020-2022 for each fishery group.

Following work examining the performance of a proposed estimation method (EM) and on the basis of SC20 guidance, two alternative metrics for HCR input are used: an absolute measure of mean estimated $SB/SB_{F=0}$ of the last three years; and a relative measure of mean estimated $SB/SB_{F=0}$ in the last three years relative to the mean estimated $SB/SB_{F=0}$ in 2017-2019.

Different combinations of HCR shape, constraint and HCR input type result in 18 MPs being evaluated.

Five performance indicators (PIs) are calculated over the 30 year projection period: $SB/SB_{F=0}$; the probability of $SB/SB_{F=0}$ being above the limit reference point; total catch in WCPFC-CA; vulnerable biomass (a proxy for catch rates) relative to the vulnerable biomass in 2020-2022; and the variability of catches in the WCPFC-CA.

An updated online app is available to explore the results: https://ofp-sam.shinyapps.io/spample

Three one-off sensitivity tests are run to explore potential impacts of: an alternative HCR baseline of 2000-2004 catches for troll fisheries in the WCPFC-CA; an alternative baseline catch level for fisheries in the EPO; EPO fisheries being managed through the MP.

Finally, a dry run analysis is performed in which a candidate MP is evaluated using the most recent data up to 2022 to explore what the resulting catch limits would be under different HCR constraints and HCR input metrics.

1 Introduction

The management strategy evaluation (MSE) framework comprises a grid of operating models (OMs) that generate test data and consider a broad range of uncertainties, and a suite of candidate management procedures (MP) that set fishing opportunities based on the estimated status of the stock (Punt et al., 2014). Performance indicators (PIs) are calculated using the resulting 'true' data in the OMs. The relative performance of the candidate MPs are compared using the PIs.

This report describes the current MSE framework for evaluating candidate MPs for South Pacific albacore (SPA). The relative performance of the MPs is summarised, including the impact of the choice of the harvest control rule (HCR) input type, and the impact of any constraint on how much the output of the HCR can change from one management period to the next.

2 Management strategy evaluation framework

The MSE framework is similar to the one presented to SC19 (Scott et al., 2023). The key difference is the grid of OMs against which the candidate MPs are tested (Scott et al., 2024b). Additionally, the estimation method (EM) in the candidate MPs has been updated (Scott et al., 2024a).

The key assumptions and settings for the framework are:

- The simulations start in 2023 and run until 2053.
- The MP is first run in 2025 and the output applied in 2026.
- For the simulations, the catches for all fisheries in the WCPFC-CA in the period 2023-2025 are set to the average of their 2017-2022 levels.
- The management period is three years, i.e. the catch or effort limits set by the MP are applied for the following three years.
- There is a data lag of two years, e.g. when evaluating the MP in 2025, data for the EM is available up to and including 2023.
- The output of the MP is applied in the following year for the remainder of that management period, e.g. when evaluating the MP in 2025, the output fishing levels are applied in 2026-2028.
- That MP output is applied to equally to all fisheries (longline and troll) operating within the WCPFC-CA south of the equator.
- The catch or effort limits specified by the MP are always fully taken (if possible), i.e. there is no implementation error.
- The MP does not apply to fisheries operating in the EPO region of the model.
- The total catches of fisheries operating in the EPO region of the model are fixed at 22,500 mt per annum.

2.1 Operating models

The operating model (OM) grid has been updated to use the 2024 stock assessment (Scott et al., 2024b; Teears et al., 2024). There are 200 pairs of steepness and natural mortality values, sampled independently from assumed distributions. Two levels of historical recruitment are used on which to base future variability: 1973-2020 and 2000-2020. Two levels of effort creep are applied to the longline fisheries only: 0% and 1% per annum. A factorial combination of these factors gives 800 OMs.

All fisheries in the OMs are managed by setting catch limits. Future work may explore fisheries potentially being managed by effort limits, if managers request this be examined.

Stochasticity is included in the projections by applying randomly sampled recruitment deviates to the recruitment calculated by the stock-recruitment relationship. Each OM uses different samples of recruitment deviates so that the projected recruitment for each of the OMs is different.

Observation error with a CV of 20 is applied to the catch and catch-per-unit of effort (CPUE) data used by the EM.

3 Performance indicators

Five performance indicators (PIs) are calculated.

- $SB/SB_{F=0}$ in the WCPFC-CA (measured as $SB_{latest}/SB_{F=0}$, i.e. SB in year y relative to the average $SB_{F=0}$ in years y-10 to y-1). This can be compared to the interim target reference point (TRP) and any proposed alternative TRPs.
- Probability of the stock status being above the limit reference point (LRP), noting that the WCPFC requires the probability to be greater than 0.8.
- Total catch in the WCPFC-CA.
- Catch variability, calculated as the absolute annual difference in total WCPFC-CA catch.
- Vulnerable biomass available to longline fisheries in the WCPFC-CA. This is a proxy for CPUE and is calculated as relative to the average vulnerable biomass in the period 2020-2022.

The average values of the PIs are calculated over three time periods:

- Short (2026-2034)
- Medium (2035-2043)
- Long (2044-2052)

4 Management procedures

An MP comprises three components:

- Data collection
- Estimation method (EM)
- Harvest control rule (HCR)

For each candidate MP examined here the data collection is the same and is assumed to be similar to current data collection processes. The EM and HCRs are explored below.

The current key assumptions for the MPs are:

- All fisheries managed by the MP (longline and troll fisheries within the WCPFC-CA) are managed by catch limits.
- The HCR of each MP outputs a scaler that is applied to the baseline catch for each fishery group managed by the MP.
- The current baseline catch for each HCR is the average catch in the period 2020-2022 within the WCPFC-CA, i.e. an output scaler of 1 sets the catch limit for the next management period to the average of 2020-2022 catches by fishery group (a sensitivity test is conducted below in which the troll fisheries in the WCPFC-CA have a different baseline).
- All fisheries managed by the MP are affected equally, e.g. if the MP specifies a 10% increase in catch, all fisheries managed by the MP have their catch limits increased by 10% relative to the baseline for the next management period.

4.1 Estimation method and input to the HCR

Each candidate MP uses the same estimation method (EM) based on an age-structured production model (ASPM) implemented in Multifan-CL (Scott et al., 2024a, see Table 3 for settings) . Two metrics of stock status are estimated by the EM that are used as alternative inputs for the HCRs:

- Absolute: mean $SB/SB_{F=0}$ of the last three years
- Relative: mean $SB/SB_{F=0}$ of the last three years relative to the mean $SB/SB_{F=0}$ in 2017-2019

The second metric is a relative measure of $SB/SB_{F=0}$ and is designed to reduce the bias resulting from uncertainty in the true value of natural mortality (Scott et al., 2024a).

As noted above, $SB/SB_{F=0}$ is measured as $SB_{latest}/SB_{F=0}$, i.e. SB in year y relative to the average $SB_{F=0}$ in years y-10 to y-1, and is averaged over the last three years in the calculations above.

Currently a CPUE index based on the troll fishery is included in the EM. To improve future robustness, the performance of the EM if that index is dropped will be examined in the future.

4.2 Harvest control rules

The candidate MPs have four basic HCR shapes (Figure 1, Table 1). HCRs 1 to 3 have a similar shape to the HCR in the adopted interim skipjack MP, with a Hillary step. HCR 4 is a simpler 'hockey stick' shape.

HCR 2 has a higher maximum output and is designed to achieve lower stock levels than HCR 1, whereas HCR 3 has a lower maximum output and is designed to achieve higher stock levels than HCR 1.

Testing the EM suggested that there is a positive bias between estimates of stock status returned from the EM compared to the true stock status of the OM (Scott et al., 2024a). To compensate for these differences the shapes of the HCRs have been transformed using the fitted linear relationships in Table 1 of Scott et al. (2024a). The $SB/SB_{F=0}$ coordinates of the HCRs are therefore higher than if the true stock status was known.

For example, if the stock status was perfectly estimated by the EM, the minimum absolute $SB/SB_{F=0}$ coordinate of the HCR could be set at 0.2 (the LRP), i.e. catch limits decrease if stock status decreases towards the LRP. For the HCRs presented here, this value has been transformed to 0.27, which taking the EM bias into account should give equivalent behaviour.

Each HCR shape has two variants depending on the two input types from the EM: absolute and relative stock status (see above). The relative variant attempts to be the same as the absolute variant by rescaling the x-axis.

Most of the candidate MPs have constraints on how much the output of the HCR can change between management periods. The constraint options are +-5% and +-10%. An additional asymmetric constraint option is also included for one of the MPs, +10% -5%, i.e. a maximum 10% increase is allowed but the maximum decrease is only 5%. Options involving no constraints are also included.

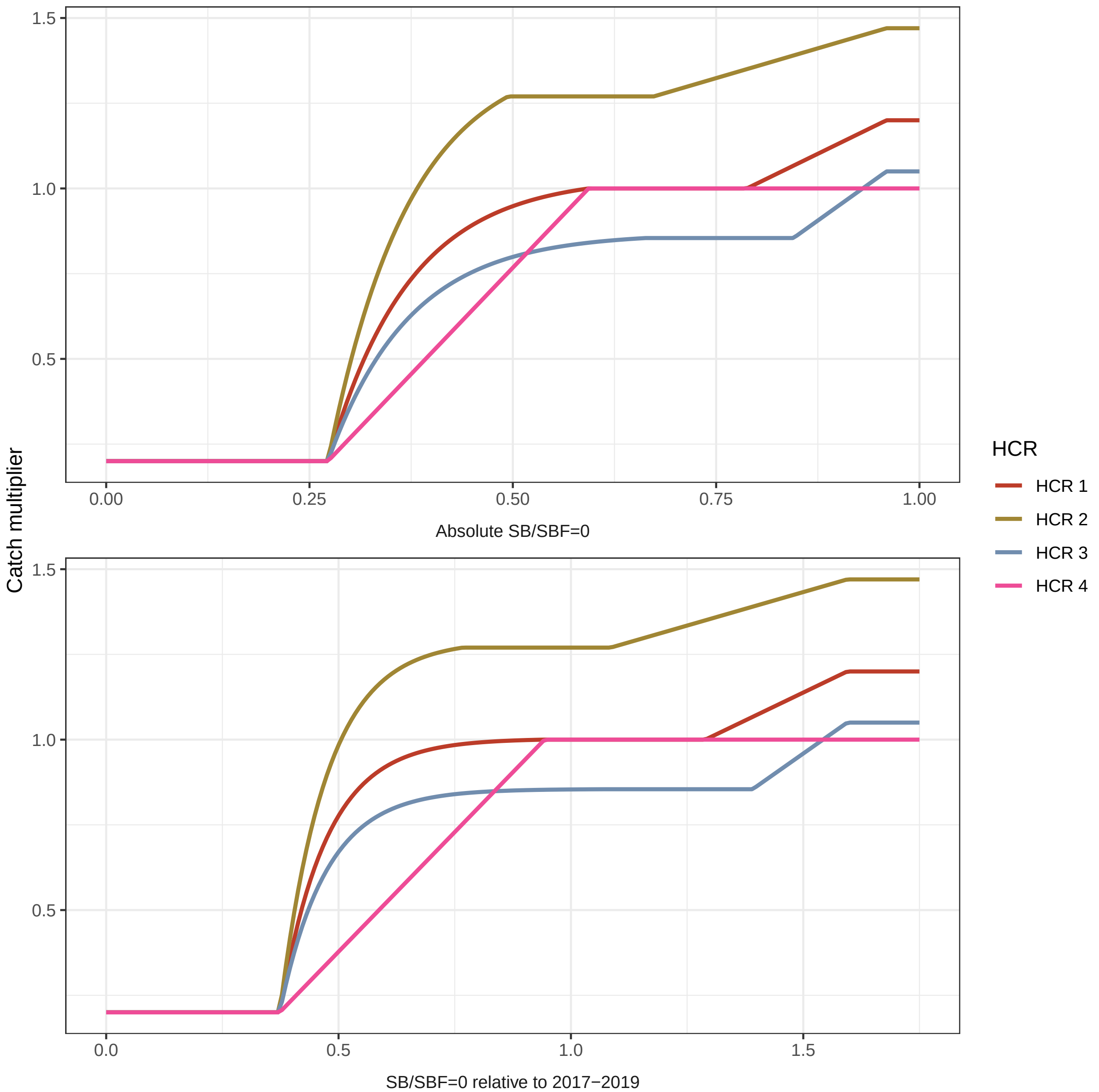

Figure 1: The basic HCR shapes. Each shape has two variants depending on the input type, either absolute mean $SB/SB_{F=0}$ of the last three years or mean $SB/SB_{F=0}$ of the last three years relative to 2017-2019.

Table 1: Parameter values of the HCR shapes, split by absolute and relative input.

HCR		Limit	Threshold	Step end	Maximum
Absolute HCR input					
HCR 1	SB/SBF=0	0.27	0.59	0.79	0.96
	HCR output	0.2	1	1	1.2
HCR 2	SB/SBF=0	0.27	0.49	0.67	0.96
	HCR output	0.2	1.27	1.27	1.47
HCR 3	SB/SBF=0	0.27	0.66	0.84	0.96
	HCR output	0.2	0.85	0.85	1.05
HCR 4	SB/SBF=0	0.27	0.59		
	HCR output	0.2	1		
Relative HCR input					
HCR 1	SB/SBF=0	0.37	0.94	1.29	1.59
	HCR output	0.2	1	1	1.2
HCR 2	SB/SBF=0	0.37	0.77	1.09	1.59
	HCR output	0.2	1.27	1.27	1.47
HCR 3	SB/SBF=0	0.37	1.07	1.39	1.59
	HCR output	0.2	0.85	0.85	1.05
HCR 4	SB/SBF=0	0.37	0.94		
	HCR output	0.2	1		

The HCR shapes are combined with different constraint options (Table 2). HCR 1 has an example of an asymmetrical constraint where the output can increase by up to 10% from the previous management period, but can only decrease by up to 5%.

Table 2: The constraint options for the candidate MPs

HCR shape	constraint
HCR 1	None; +-5%; +-10%; +10%, -5%
HCR 2	+-5%; +-10%
HCR 3	+-5%; +-10%
HCR 4	+-10%

Considering the different combinations of HCR shape, input type and constraint option there are 18 candidate MPs.

5 Results

As mentioned above 800 simulations (known as iterations) are performed for each MP. In some of the simulations the projected stock crashes due to a combination of low recruitment, life history parameter combinations implying a less productive stock, and high fishing pressure. In these cases the expected catch and stock status for the remainder of the simulation are set to zero.

The large number of MPs evaluated can make it difficult to fully analyse the results in a report. A brief summary is presented here, as well as analyses of the impact of the catch limit change constraints, and of the choice of HCR input type.

An online app, SPAMPLE, for exploring the results is available which may assist in selecting preferred MPs: https://ofp-sam.shinyapps.io/spample.

The range of expected $SB/SB_{F=0}$ for each candidate MP can be seen in Figure 2. WCPFC20 agreed an interim TRP as 0.96 x mean $SB/SB_{F=0}$ in 2017-2019. A TRP range of 0.42 to 0.56 was also proposed at WCPFC20 for examination. These values have been rescaled for the current OM grid and are shown as the top three horizontal dashed lines, the middle line being the iTRP.

Generally, MPs with HCR 1 gets the median expected $SB/SB_{F=0}$ close to the iTRP in all three time periods. MPs with HCRs 2 and 3 get the median $SB/SB_{F=0}$ close to the lower and upper proposed TRPs respectively. This could help inform which MPs to focus on. For example, if being at the iTRP is considered to be important then only MPs based on HCR 1 and 4 should be considered. The other MPs could then be eliminated making the selection of preferred MPs easier.

All MPs have a probability greater than 0.8 of being above the LRP. MPs based on HCR 2 have the lowest probability of being above the LRP (Figure 2). The relative vulnerable biomass follows a similar pattern to the $SB/SB_{F=0}$ results, with MPs based on HCR 3 having highest levels of vulnerable biomass, and therefore CPUE. MPs based on HCR 1 achieve slightly lower levels of vulnerable biomass than seen in the 2020-2022 period and MPs based on HCR 2 achieve about 80% of the level seen in the 2020-2022 period.

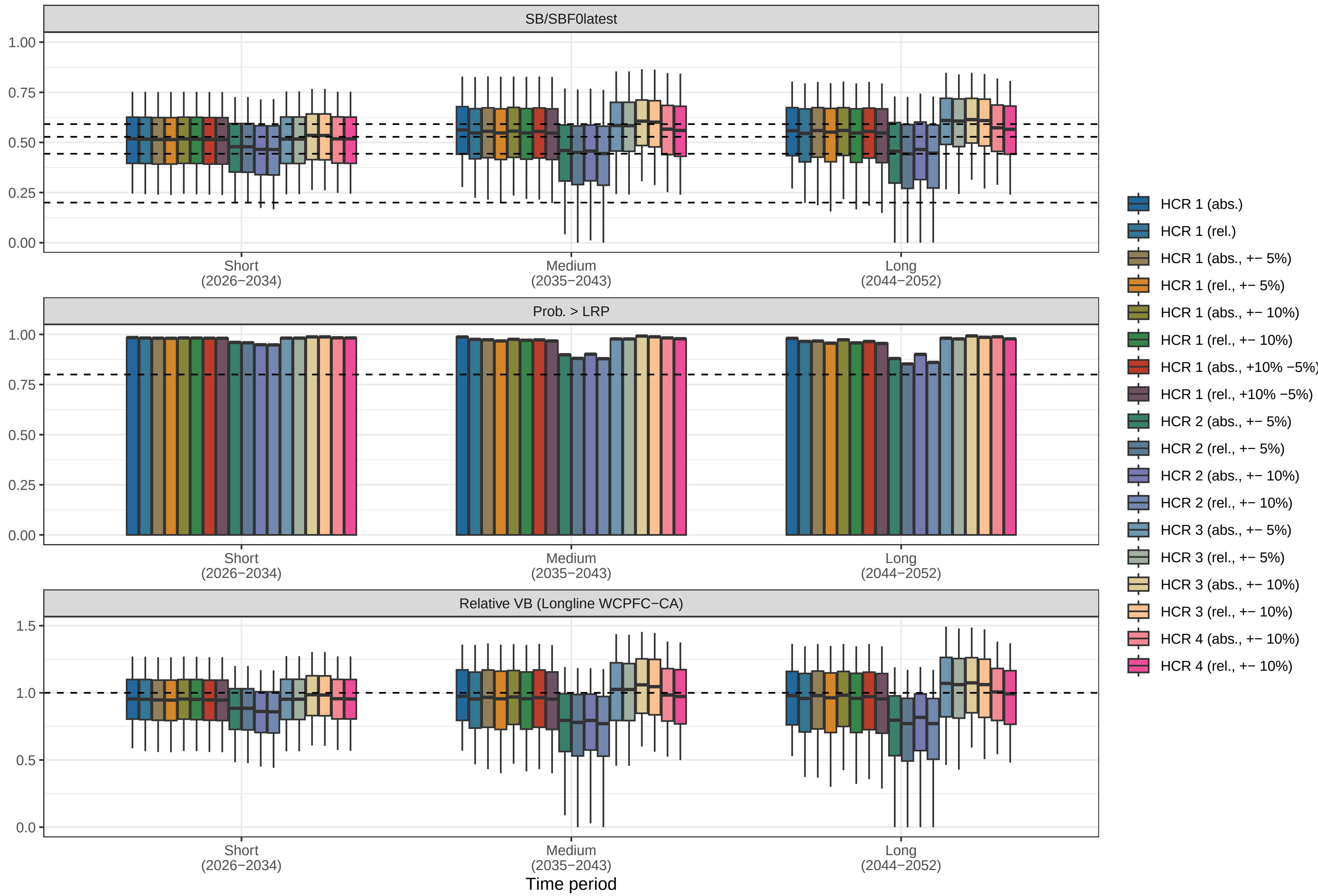

Figure 2: Box plots of $SB/SB_{F=0}$ and vulnerable biomass for the longline fisheries relative to the level in 2020-2022, and a bar plot of probability of being above the LRP for each of the candidate managment procedures across the three time periods. The tails show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. Horizontal lines on the $SB/SB_{F=0}$ plot are the iTRP, proposed TRPs from WCPFC20 and the LRP. The horizontal line on the Prob. > LRP plot is at 0.8, the minimum required by WCPFC.

The expected catches are conditional on the shape of the HCR in the MP and also the presence of any constraint on the MP output (see the section below) (Figure 3). The larger the box and the longer the tails, the greater the uncertainty in the expected catches.

As expected, MPs based on HCR shape 2 have higher levels of catch. Generally, the higher the catches, the greater uncertainty about them.

The impact of using an absolute or relative measure of stock status as the input to the HCR is discussed below.

The long tails seen for MPs based on HCR 2 in the medium- and long-term are a result of the stock crashing in some iterations, due to a combination of high fishing pressure, less productive stock assumptions, and low recruitment. For these iterations the catches are set to 0 for the remainder of the simulation.

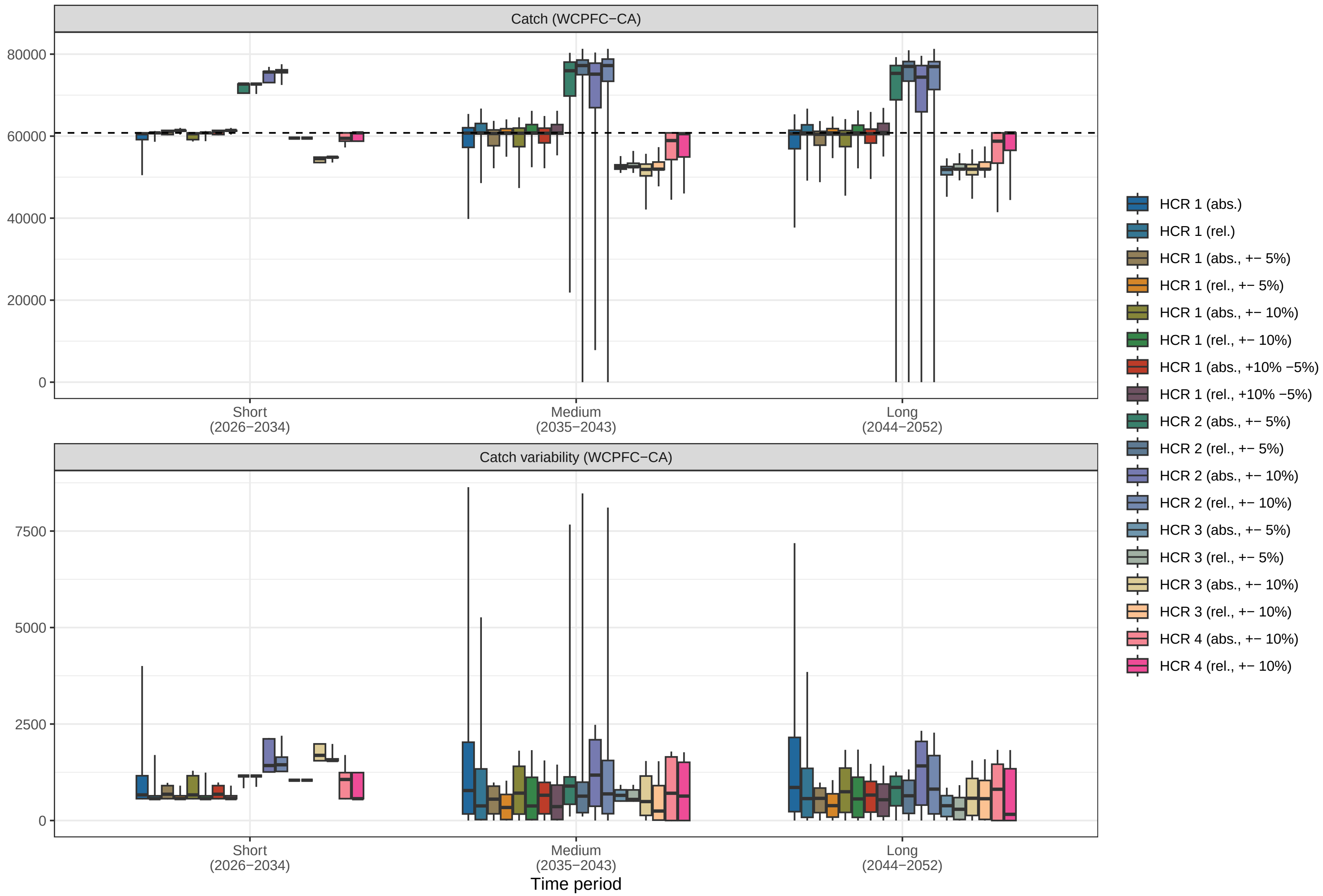

Figure 3: Box plots of catch in the WCPFC-CA and the associated average annual catch variability for each of the candidate managment procedures across the three time periods. The tails show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The horizontal line on the catch plot is the HCR baseline, the average catch in 2020-2022.

5.1 Impact of catch limit change constraints

In this section the impact of a constraint on the permissible change in MP output between management periods is examined. MPs based around HCR shape 1 and using the absolute HCR input type are used for examples. These MPs include no constraints, +- 5%, +-10% and an asymmetrical constraint of -5%, +10%.

Including a constraint on how much the output of the MP can change between management periods can help provide stability to the fishery by reducing fluctuations in catch or effort limits. However, tight constraints may prevent appropriate management action being applied. For example, a constraint may prevent sufficient reductions in catch or effort limits if the stock declines towards the LRP.

For example, Figure 4 compares the expected total catch and $SB/SB_{F=0}$ between the same HCR shape but with different constraints for a single iteration. The same iteration is used, i.e. the recruitment variability is the same, so that the results are directly comparable. In this example, the MP without constraints makes a large reduction in catch in 2032, the third management period, to almost a third of the catches in the previous management period. The MPs with constraints are not able to reduce catches by that amount. While having a constraint protects the industry from sudden reductions in the catch limit, for this iteration this results in the $SB/SB_{F=0}$ falling below the LRP for a period for those MPs with constraints.

This is an example of a trade-off. A tighter constraint means greater stability for the industry, but may lead to a higher probability of falling below the LRP.

For MPs based on HCR 1, including a constraint does not strongly affect the probability of falling below the LRP (Figure 2). However, not having a constraint leads to higher catch variability. This reinforces the idea that a level of constraint, as well as the shape of the HCR, should be considered when choosing preferred MPs.

This can also be seen in Figure 5, which shows the HCR inputs and outputs of the same iteration as in Figure 4 superimposed on the HCR shape. Without a constraint the points lie exactly on the HCR shape and can move position freely between management periods. With a constraint, the points seldom lie on the HCR shape as the final HCR output can only change by a limited amount. The performance is therefore impacted by the constraint.

Note that not all iterations show such a strong contrast in performance between different constraint options as seen in Figure 4 and Figure 5.

A final example of the impact of constraints can be seen by plotting the uncertainty in the MP output each time the MP is called (Figure 6).

For these MPs, there is almost no uncertainty in the output for the first two management periods. After that, the level of uncertainty in the catch is influenced by the constraint. The tighter the constraint, the smaller the uncertainty.

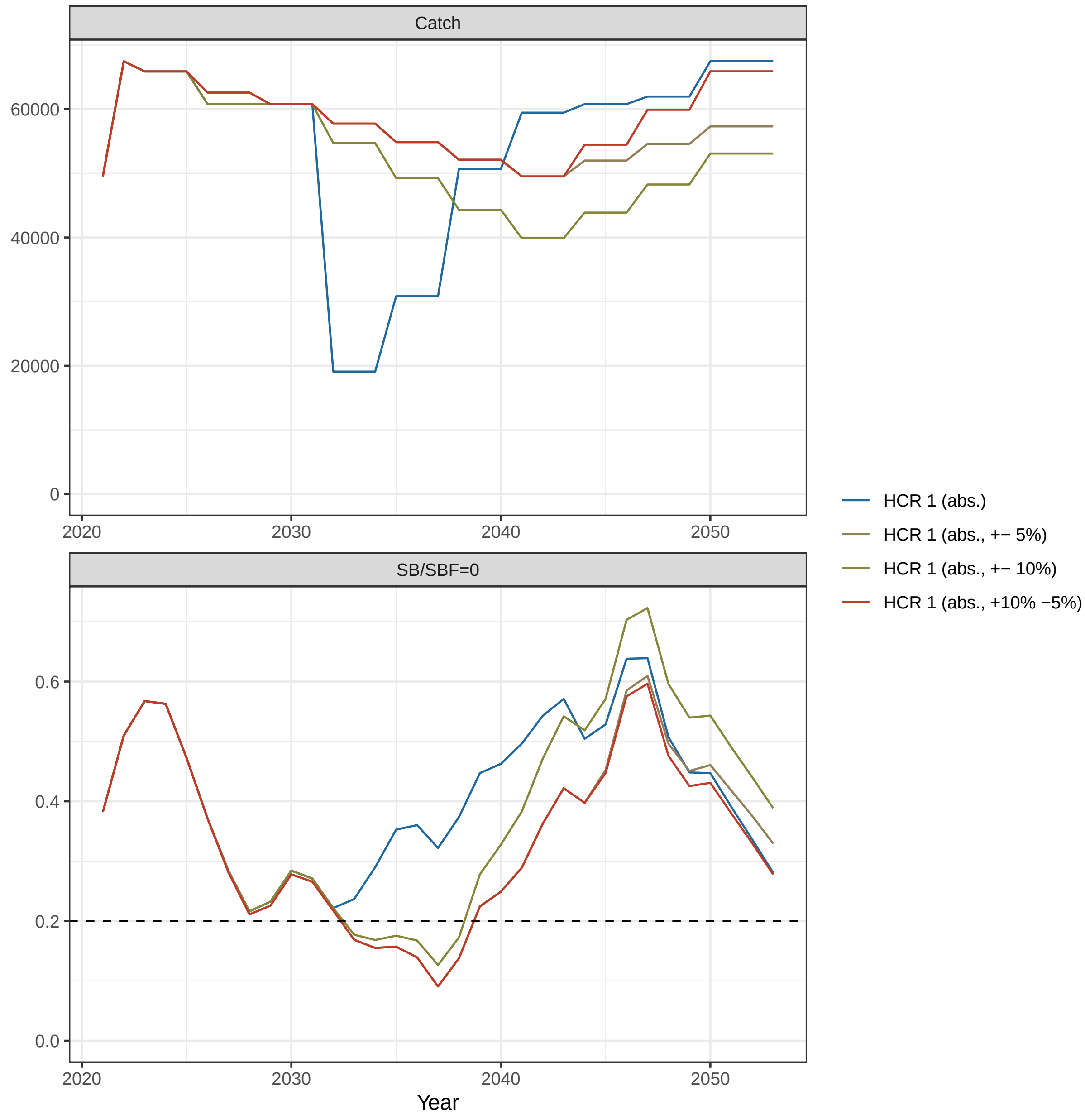

Figure 4: An example iteration of the expected total catch and $SB/SB_{F=0}$ in the WCPFC-CA from the same HCR shape but with different constraints.

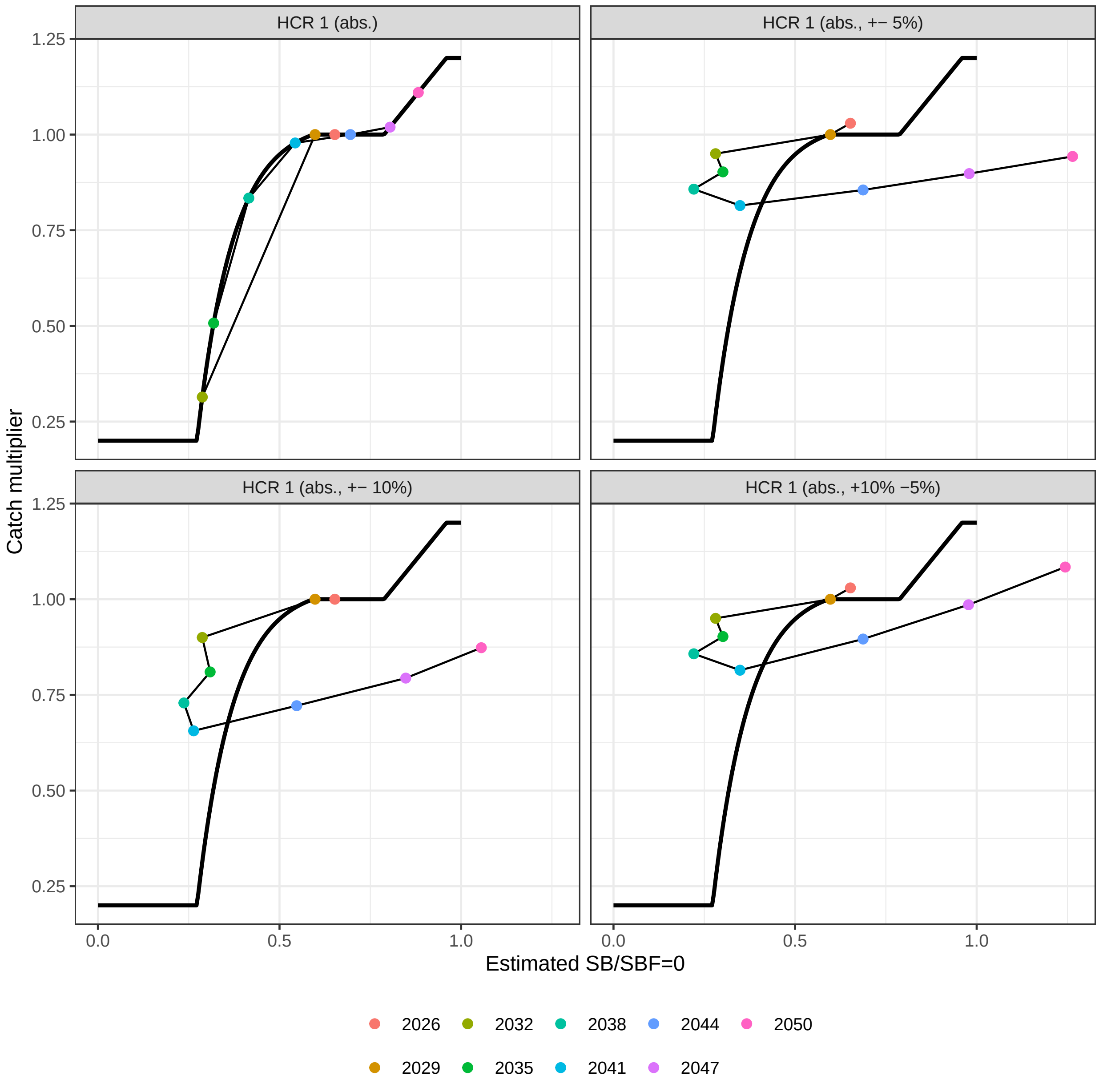

Figure 5: The inputs and outputs of a single iteration of MPs with the same HCR shape but with different constraints. There are nine management periods of three years each.

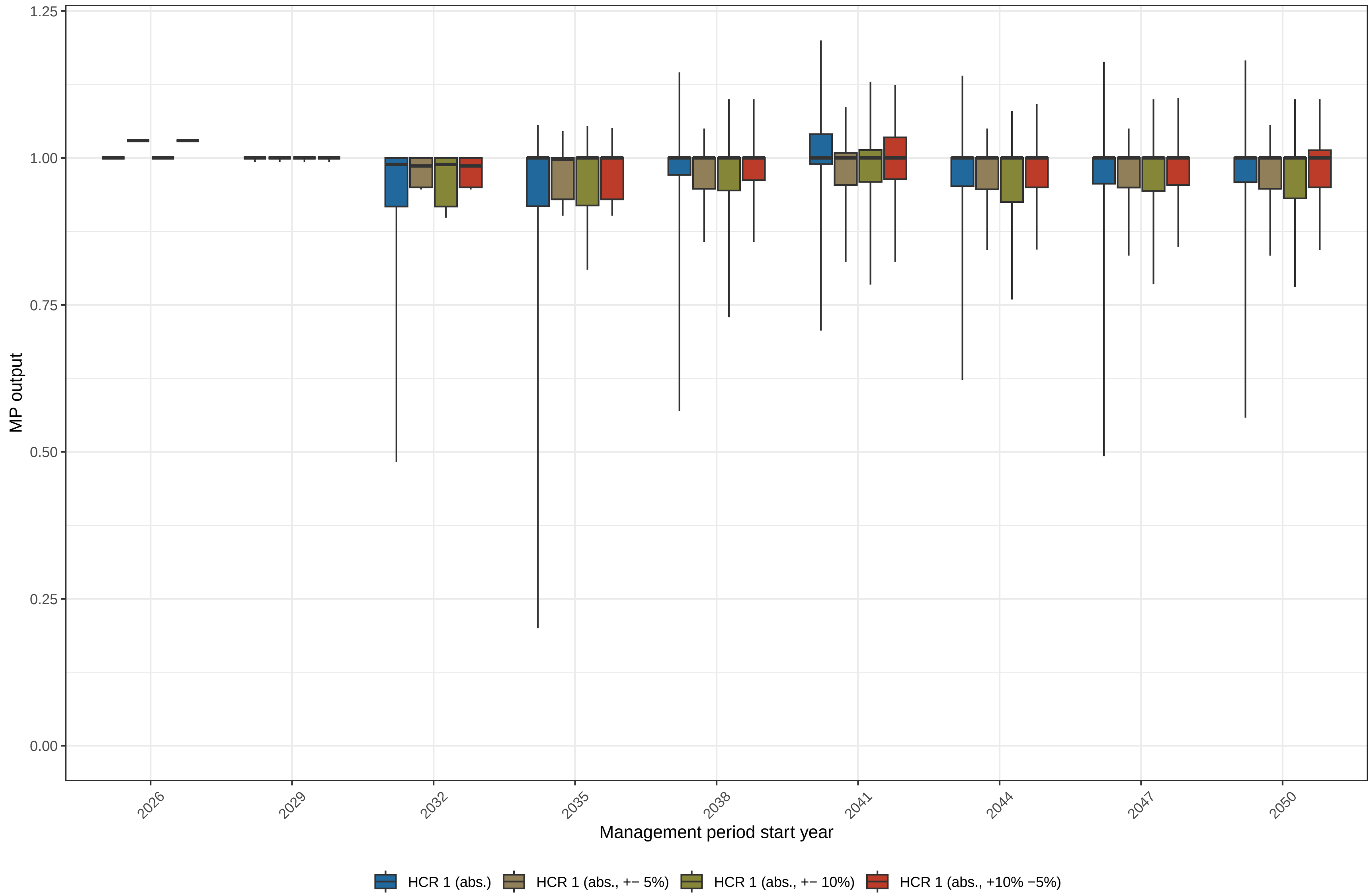

Figure 6: Box plots of the HCR output for candidate MPs with HCR 1 shape in each management period. An output of 1 sets the catch limit to be the average catch in the period 2020-2022. The tails show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value.

5.2 Impact of input type

As mentioned above, the candidate MPs presented here have two alternative inputs from the EM to the HCR: absolute or relative. A relative measure may be preferred as it can overcome uncertainty in the assumption of natural mortality in the EM (Scott et al., 2024a).

Comparing the 'true' HCR input from the OMs to the estimated HCR input from the EM for all iterations across all candidate MPs reinforces this result (Figure 7). Using a relative measure gives better correspondance between the true and estimated values. However, both measures show a degree of bias, with the EM tending to provide slightly 'optimistic' stock status estimates. As mentioned above, an attempt to account for this bias has been made through the shape of the HCRs, reflecting that data collection, EM and HCR work as a package to form the MP.

The PIs for two MPs based on HCR 1 with a +- 10% constraint but different HCR input types are compared in Figure 8. The main difference is in the uncertainty around the catches where using a relative input type gives lower uncertainty (smaller boxes and shorter tails) and also lower catch variability. A relative input type also yields a slightly more positive trend in catches but a small trade-off in vulnerable biomass. This appears to be a general pattern across all of the MPs.

For MPs based on HCR 2 using a relative measure gives a lower probability of being above the LRP. This can potentially be improved by adjusting the HCR shape of the relative variant, i.e. perhaps by shifting the end of the Hillary step to compensate.

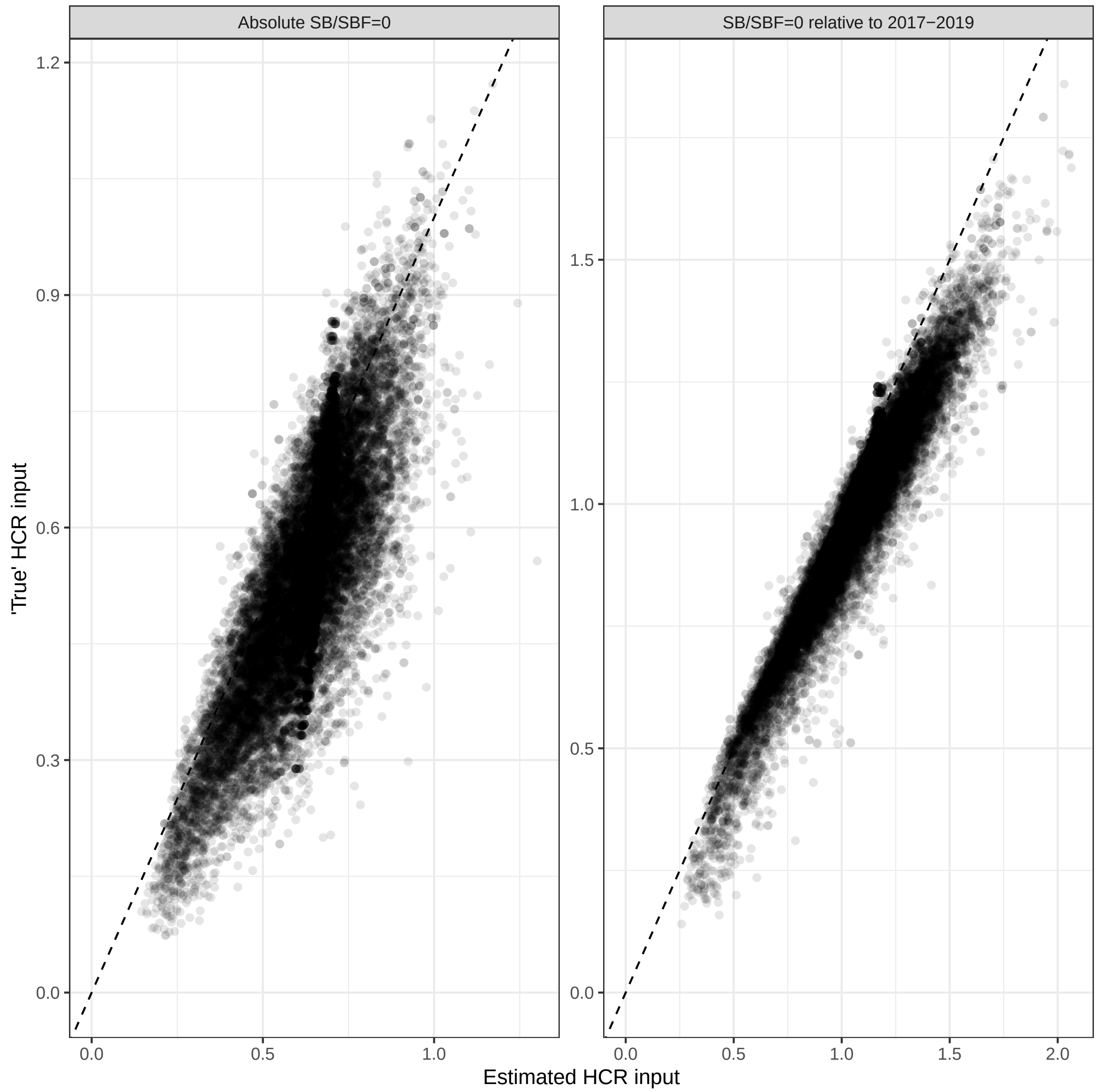

Figure 7: Comparing the 'true' HCR input to the estimated HCR input for all iterations across all candidate MPs for each input type. The dotted line has a slope of 1 and an intercept of 0.

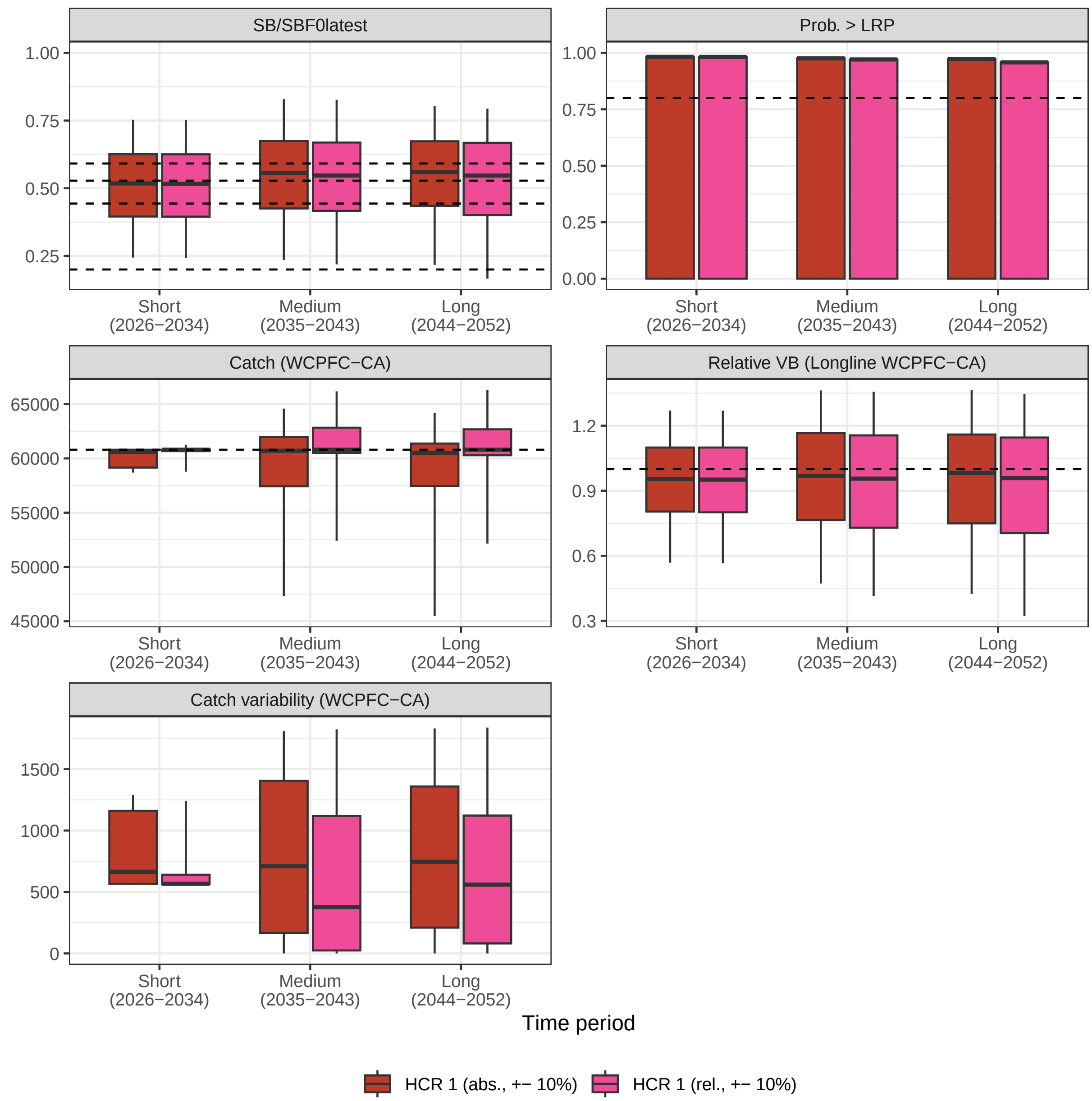

Figure 8: The five performance indicators for two MPs with the same HCR shape and the same constraint but different HCR input type. The tails show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The probability of being above LRP is shown as a bar plot.

5.3 Sensitivity tests

Various one-off sensitivity tests are performed. These evaluations only use an MP based on HCR 1, a +- 10% constraint and use an absolute input to the HCR. The results of the single change are then compared to the results from that original MP.

Troll fishery with different baseline

The evaluations performed above use an HCR baseline of average catches in the period 2020-2022 for all fisheries in the WCPFC-CA. In this one-off sensitivity, the baseline period for the troll fisheries in the WCPFC-CA is changed to 2000-2004, i.e. an output scaler of 1 sets the troll fisheries in the WCPFC-CA to the average catch level in 2000-2004, but for all other fisheries sets it to the average catch level in 2020-2022 (Figure 9).

In the OM grid the average troll fishery catch in the WCPFC-CA in the period 2000-2004 is 5240 mt compared to 4783 mt in the period 2020-2022. The difference in the baseline levels results in only small differences in the results (Figure 9). For example, the expected catches are slightly higher with the troll baseline as 2000-2004.

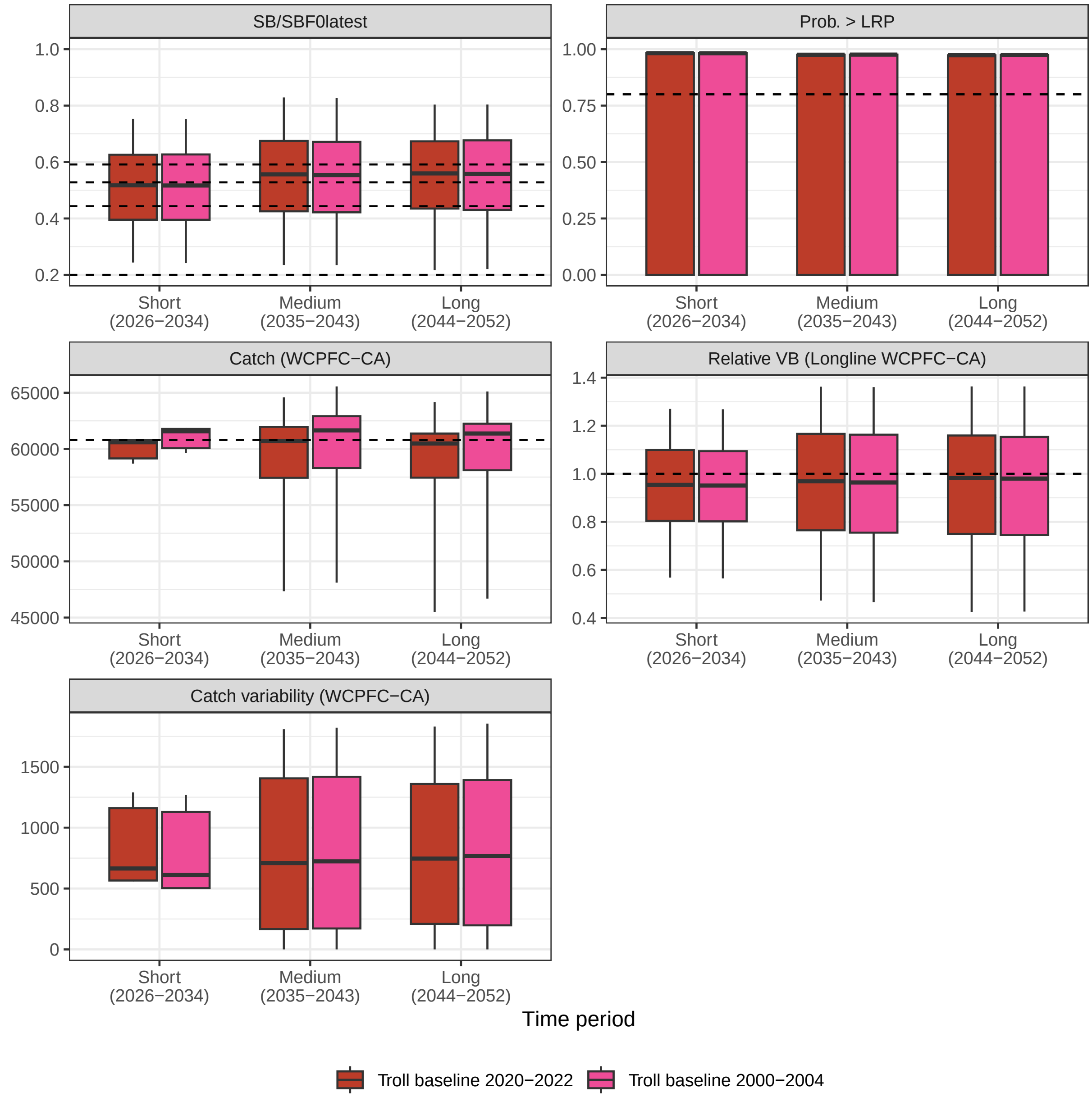

Figure 9: The five performance indicators for when the HCR baseline for all fisheries is 2020-2022 catches and when the HCR baseline for the troll fisheries in WCPFC-CA is 2000-2004 catch. A HCR 1 shape is used, with +- 10% constraint and an absolute HCR input. The tails show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The probability of being above LRP is shown as a bar plot.

EPO baseline

In the evaluations performed above the fisheries in EPO are not managed through the MP and their future catches are fixed at 22,500 mt per annum. As a sensitivity test the future catches are fixed at a lower level of 15,000 mt per annum (Figure 10).

Lower catches in the EPO result in higher expected stock status and vulnerable biomass in the WCPFC-CA. The catches in the WCPFC-CA are also higher, with reduced uncertainty and lower variability.

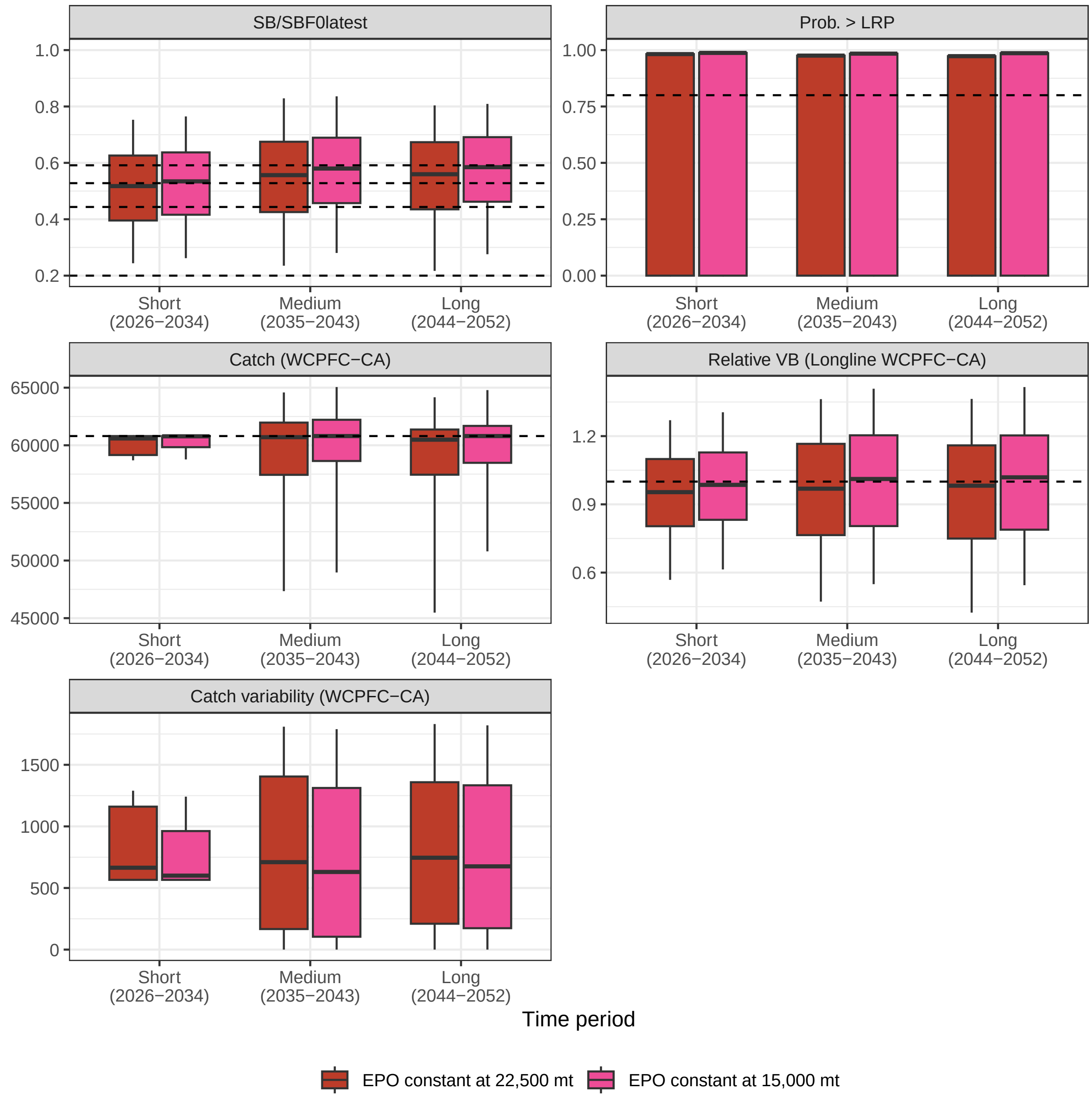

Figure 10: The five performance indicators for when the constant catch level in the EPO is 22,500 mt and 15,000 mt. A HCR 1 shape is used, with +- 10% constraint and an absolute HCR input. The tails show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The probability of being above LRP is shown as a bar plot.

EPO included in the MP

In the evaluations above only fisheries in the WCPFC-CA are managed through the MP and the fisheries in the EPO have a constant level of future catches of 22,500 mt per annum. Here, the EPO fisheries are also managed through the MP. This can be interpreted as a 'compatible measures' scenario. The HCR baseline for the EPO fisheries is 22,500 mt, i.e. an output MP scaler of 1 means that the catch limit for EPO fisheries is set to 22,500 mt.

The EM only estimates the stock status in the WCPFC-CA, not the combined model area. The reported PIs are also based exclusively on the WCPFC-CA.

The results for this test are broadly the same as when only the WCPFC-CA fisheries are managed through the MP (Figure 11).

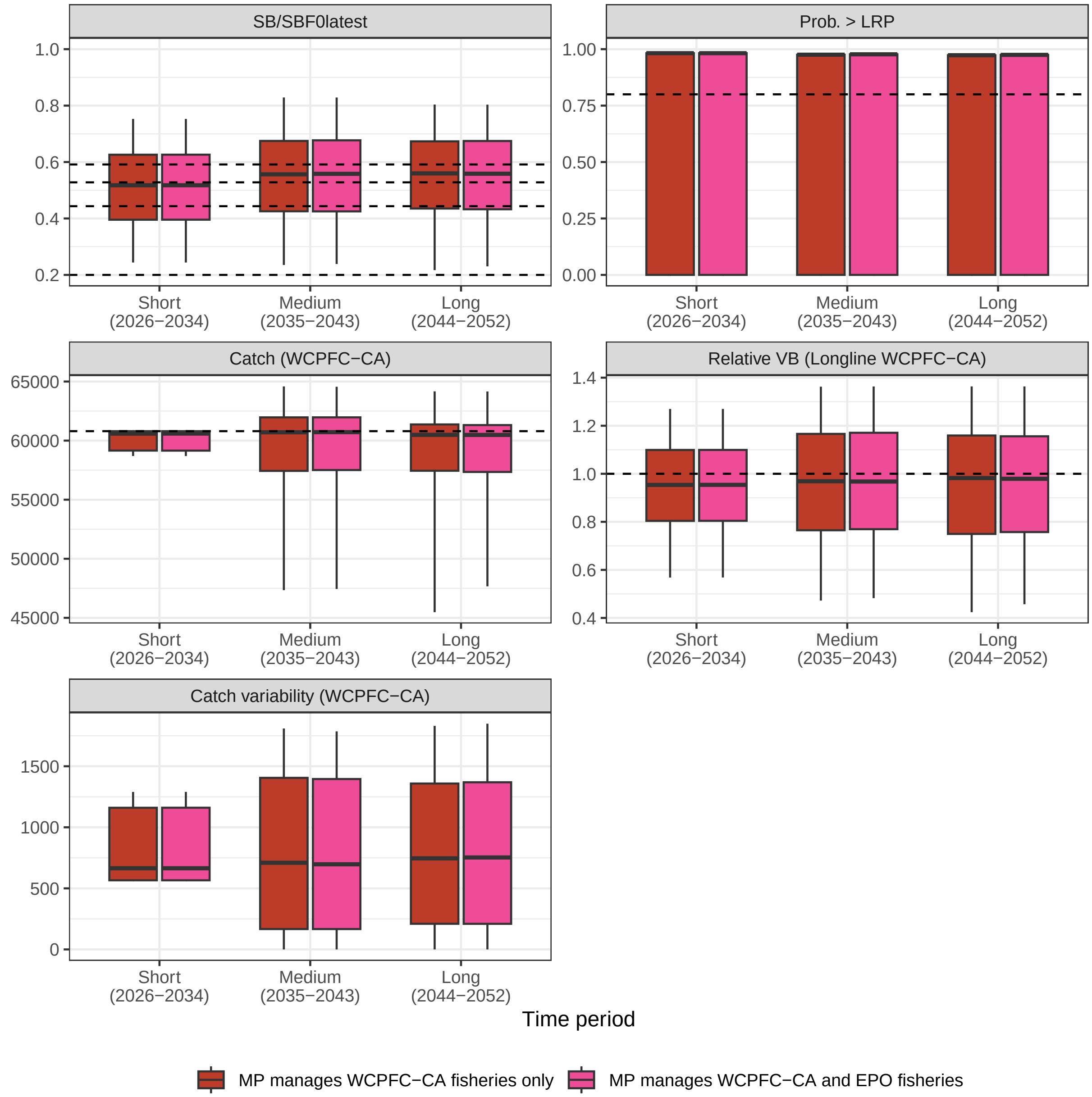

Figure 11: The five performance indicators for when the EPO fisheries are also managed through the MP, with a baseline of 22,500 mt. A HCR 1 shape is used, with +- 10% constraint and an absolute HCR input. The tails show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The probability of being above LRP is shown as a bar plot.

6 Dry run analysis

In this section a 'dry run' of a candidate MP is performed, using the most recently available data up to 2022. For this analysis, an MP based on HCR shape 1 is used. The potential impacts of different constraints and different HCR input types are explored.

The EM ran successfully to convergence with a maximum gradient of 8.6e-7. The predicted CPUE of the three index fisheries tracks the observed CPUE (Figure 12).

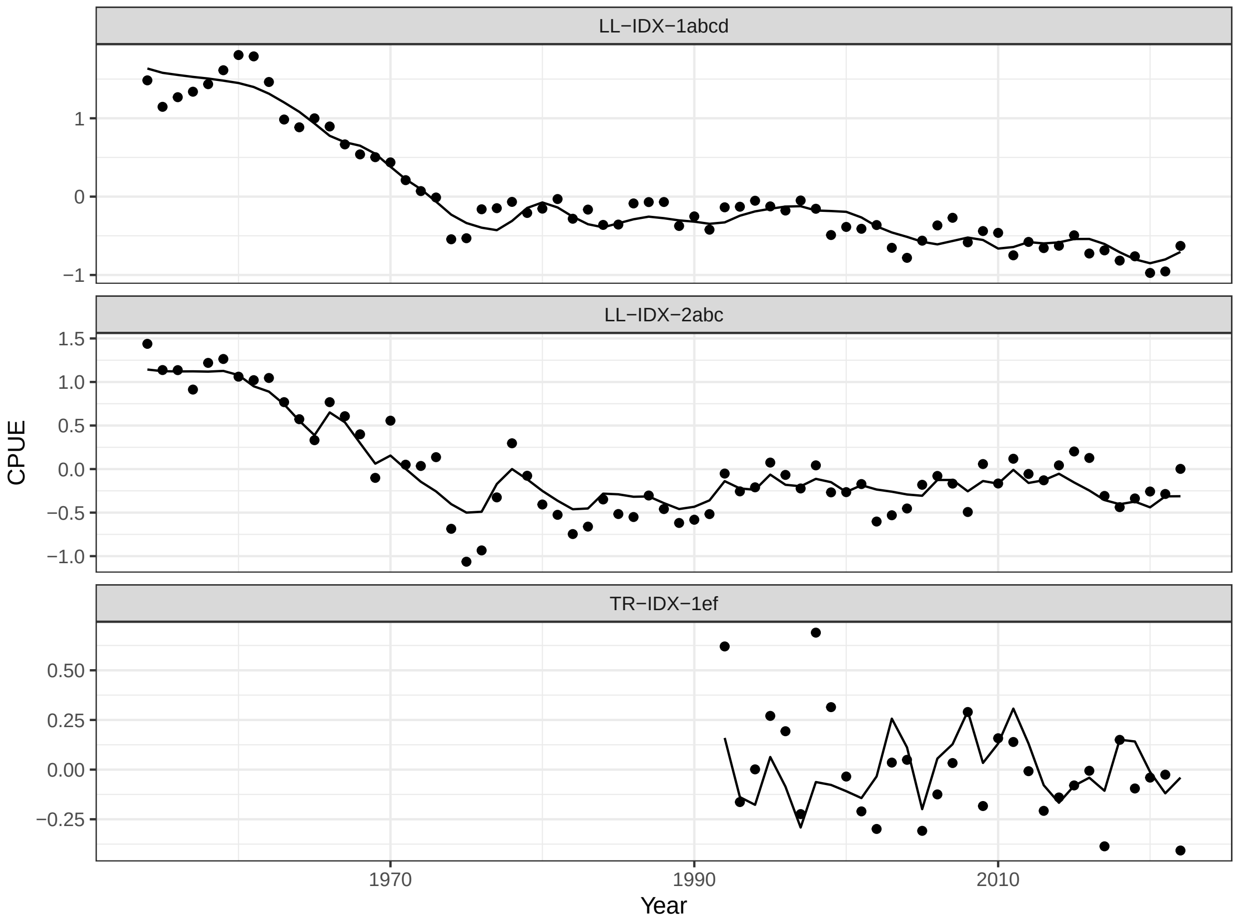

Figure 12: Observed (points) and predicted (lines) CPUE for the index fisheries from the EM for the dry run analysis.

For this analysis both the absolute and relative measures of stock status for the HCR are calculated. The absolute HCR input is calculated as 0.5918. Note that we expect this to be different to the most recent estimate from the 2024 stock assessment because the EM is different to the stock assessment model. The relative HCR input is calculated as 1.0844.

Using HCR shape 1 with no constraint for these inputs would give an output scaler of 0.9995 for the absolute version and 1 for the relative version.

For the constraint to be applied it is necessary to calculate the scaler in the previous time period.

Here we use the WCPFC-CA catch level in 2022, the last data year, relative to the HCR baseline of mean WCPFC-CA catch in the period 2020-2022. This scaler is calculated as 1.1098. With a +- 10% constraint, the new output scaler cannot change by more 10% from this original scaler. A 10% reduction of this original scaler gives a minimum new scaler of 0.9989, i.e. the constraint does not limit the new output scaler in this instance.

The new catch limit for the next management period would therefore be set at 0.9995 or 1 x the baseline catch for the absolute and relative measures respectively (Figure 13).

If a tighter constraint of +- 5% had been used then the constraint would have limited the new scaler to 1.0543 for both the absolute and relative measures, i.e. the new catch limit would be set at 5.43% higher than the baseline.

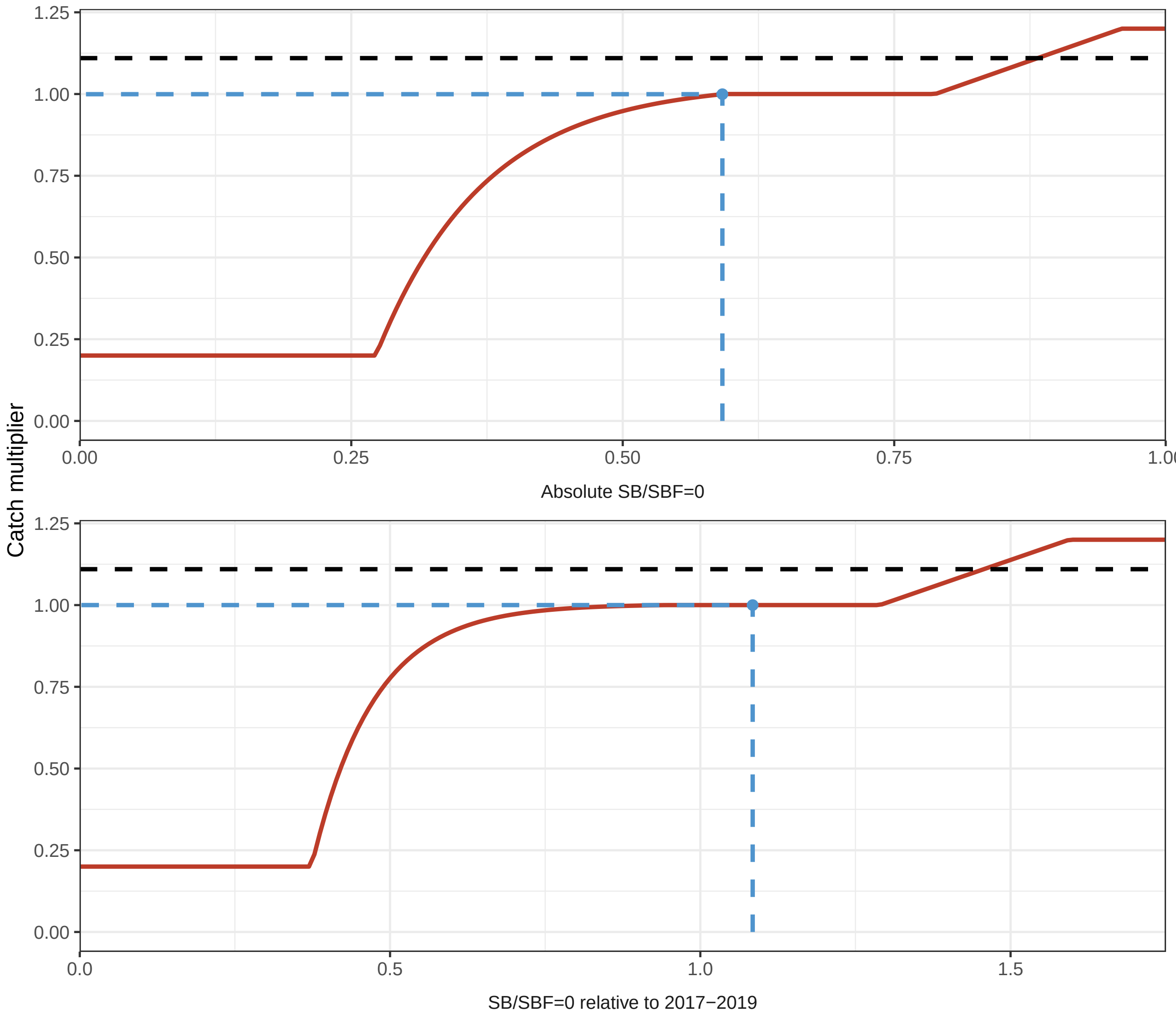

Figure 13: The result from the dry run analyses, using input data up to 2022 and example MPs based on HCR 1, with a +- 10% constraint with either an absolute or relative estimate of stock status as the HCR input. The estimated stock statuses from the EM are used as inputs to the HCRs, and shown as the vertical blue lines. The horizontal blue lines shows the resulting output scalers. The horizontal black dashed line shows the scaler in the previous time period: the catch level in 2022, relative to the baseline catch level (the average of 2020-2022). The +- 10% constraint on the HCR would prevent the output of the HCR from being more than 10% away from the previous scaler, although in this example the constraint does not affect the output.

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References

Punt, A., Butterworth, D., de Moor, C., De Oliveira, J., and Haddon, M. (2014). Management strategy evaluation: best practices. *Fish and Fisheries*, (DOI:10.111/faf12104).

Scott, F., Scott, R., and Yao, N. (2024a). Testing and developing an estimation method for South Pacific albacore. Technical Report WCPFC-SC20-2024/MI-WP-05, Manila, Philippines, 14–21 August 2024.

Scott, F., Scott, R., Yao, N., and Natadra, R. (2023). Evaluation of candidate management procedures for South Pacific albacore. Technical Report WCPFC-SC19-2023/MI-WP-06, Koror, Palau, 16–24 August 2022.

Scott, R., Scott, F., Yao, N., Hamer, P., and Pilling, G. (2024b). Selecting and Conditioning Operating Models for South Pacific Albacore Rev.01. Technical Report WCPFC-SC20-2024/MI-WP-04, Manila, Philippines, 14–21 August 2024.

Teears, T., Castillo-Jordan, C., Davies, N., Day, J., Hampton, J., Magnusson, A., Peatman, T., Pilling, G., Xu, H., Vidal, T., Williams, P., and Hamer, P. (2024). Stock assessment of South Pacific albacore: 2024. Technical Report WCPFC-SC20-2024/SA-WP-02-Rev 3, Manila, Philippines, 14–21 August 2024.

Appendix: Summary of relevant SC20 outcomes

The following are relevant outcomes from SC20 (numbering follows the SC20 Outcomes Document).

5.1.2 South Pacific albacore tuna

5.1.2.1 Target reference points

106. SC20 recognized that WCPFC20 adopted an interim TRP for South Pacific albacore, defined as 4% below the estimated average spawning potential depletion of the stock over the period 2017-2019 (0.96 SB2017- 2019/SBF=0). SC20 recommended the Commission note that the biomass depletion associated with the adopted interim TRP has been re-estimated to be 50% according to the 2024 SPA stock assessment outcomes. This biomass depletion when the interim TRP was adopted by WCPFC20 was previously estimated at 47% based on the 2021 SPA stock assessment.

5.1.2.2 South Pacific albacore operating models

110. SC20 adopted the operating model reference set, together with the proposed robustness set (Table 2, SC20-MI-WP-04), for the evaluation of candidate south Pacific albacore MPs.

111. SC20 noted there are concerns about the range of uncertainty covered by the current operating model set. SC20 recommended that future work to elaborate the OM sets be conducted through the monitoring strategy and could include:

- development of scenarios for the impacts of climate change
- consideration of potential effects of effort creep and/or hyperstability in CPUE
- development of models that address uncertainties around stock structure to the robustness set.

112. SC20 recommended that simulations be conducted to explore the implications of assuming a single stock OM when there could be multiple stocks. If ongoing genetics work confirms the presence of multiple-stocks and the simulations indicate that the single-stock assumption made in the OMs is problematic, then exceptional circumstances should be considered and the OM sets should be revised to account for multiple reproductive stocks in the South Pacific.

5.1.2.3 South Pacific albacore management procedure

113. SC20 recommended that SPC focus primarily on the following two ASPM-derived estimators with a view to having a robust estimator, without obvious future data vulnerabilities:

- A direct biomass depletion approach using mean SB/SBF=0 of the last three years; and
- A ratio approach that uses Mean SB/SBF=0 of the last three year (same as in 1.a) relative to 2019-2022.

114. SC20 noted that there was bias in estimation model performance at low predicted stock sizes. SC20 recommended that this bias be addressed through the design of the HCR and its significance or otherwise will be evaluated through evaluation of candidate MPs. Should the estimation model bias become problematic in the MP design context, then steps will need to be taken to address that issue.

115. SC20 recommended that SPC conduct a Management Strategy Evaluation of a range of candidate MPs, using updated estimators together with HCR and maximum change metarule specifications similar to those presented at SC19 (SC19-MI-WP-06).

116. SC20 recommended that SPC, in addition to running projections assuming a single baseline for all fisheries within the Management Procedure evaluations, explore the potential implications of using different reference periods for different fisheries and gears within the MP.

117. SC20 recommended that EPO catches be assumed to remain constant at recent levels but with an exploration of a case where the EPO is subject to MP controls (in a similar way to SC20-MIWP-03).

118. SC20 noted that it was desirable to constrain the number of candidate MPs evaluated for consideration and recommended that steps be taken to manage this, including using one-off variations from a base-case scenario, rather than a full factorial grid of options.

119. SC20 recommended that, to the extent possible, the results of the above candidate MP evaluations be provided to the SMD and the Commission for their consideration or decision.

Appendix: Estimation model settings

Table 3: Settings for the estimation method

Model setting	Value
Regional structure	2 regions
Number of fisheries	19
Longline	13
Troll / DN	3
Index	3
Steepness	0.8
Natural mortality	Lorenzen, M12=0.36
Growth	Fixed
ML1	45.538
ML2	100.115
K	0.3932
Movement rates	Fixed (2024 assessment)
Selection patterns	Fixed (2024 assessment
Average recruitment	Last 2 years
Recruitment distribution	0.819, 0.181