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Evaluation of candidate management procedures for South Pacific albacore

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Executive summary

This report presents recent evaluations of candidate management procedures (MPs) for South Pacific albacore (SPA). It builds on previous evaluations presented at SMD02 and WCPFC21 in 2024. The main differences between the evaluations presented in 2024 and here are:

- Following the mixed fishery harvest strategy approach, the SPA MP now only applies to longline and troll fisheries operating in the region south of 10S in the WCPFC-CA. In previous evaluations, the MP applied to longline and troll fisheries operating in the WCPFC-CA, south of the equator.
- To run the evaluations it is necessary to make an assumption about future catch levels of albacore in the equator to 10S region of the WCPFC-CA. The baseline assumption here is that the future catches are fixed at 9000 mt per annum (approximately the average of 2014-2023 catches).
- The future catch levels of albacore in the EPO model region are fixed at 18,000 mt per annum (approximately the average of 2014-2023 catches). In the previous evaluations they were fixed at 22,500 met per annum.

Four candidate MPs are presented. Three are catch-based, i.e. output a catch limit, and the other is effort-based, i.e. outputs an effort limit. It should be noted that the allocation of the catch or effort limit, and how those allocations are managed in practice (e.g. through effort if the allocation is in terms of catch, or catch if the allocation is in terms of effort) is external to the MP. The candidate MPs are designed to achieve the interim target reference point (iTRP) or the proposed upper or lower TRP range, in the long-term. They have constraints on how much the output of the HCR can change between management periods.

The estimation method (EM) is an age-structured production model, implemented in Multifan-CL, as presented to SC20, SMD02 and WCPFC21. As requested by SMD02, the EM no longer considers the troll index, and only uses the longline indices in the WCPFC-CA and EPO. The EM outputs a relative indicator of stock status (average $SB/SB_{F=0}$ in the last three estimated years relative to the average $SB/SB_{F=0}$ in 2017-2019), as agreed by SMD02.

Six performance indicators are calculated to evaluate the relative performance of the candidate MPs, including expected $SB/SB_{F=0}$ (to be compared to candidate TRP levels), expected catch levels, and expected vulnerable biomass (a proxy for catch rates).

Sensitivity tests are performed for one of the candidate MPs in which the the future SPA catches in the EPO and in the equator to 10S region of the WCPFC-CA are set at 22,500 and 12,000 mt per annum respectively, i.e. higher than the baseline assumptions. These tests show that the performance of the candidate MP is not strongly affected by the alternative catch assumptions.

SC21 is invited to:

- Provide feedback on the MSE framework, including the baseline assumptions made about future catches of albacore in the EPO and equator to 10S region of WCPFC-CA.
- Agree to continue using the described estimation method, including the relative indicator of stock status.
- Provide feedback on the candidate MPs, for example ouput type (catch- or effort-based), long-term objective and constraint option.

1 Introduction

This report describes the most recent evaluations of candidate management procedures (MPs) for South Pacific albacore (SPA) following feedback and outcomes from SC20, SMD02 and WCPFC21 (See Appendices) (WCPFC, 2024a,b,c; SPC-OFP, 2024). The relative performance of the MPs is summarised through the calculated performance indicators.

The main differences between the evaluations presented here and at WCPFC21 is that fisheries operating in the area between the equator and 10S within the WCPFC-CA are no longer managed through the SPA MP. Under the mixed fishery harvest strategy approach, it is proposed that longline fisheries operating in this area, referred to as the tropical longline (TLL) fishery, will be managed through the bigeye MP, i.e. their fishing levels will not consider the stock status of SPA. Catch levels of albacore in the equator to 10S region of the WCPFC-CA make up about 12% of recent (2020-2022) total SPA catch in the WCPFC-CA. It is therefore important that any adopted SPA MP is robust to different levels of catch by the TLL.

To run the candidate SPA MP evaluations, assumptions need to be made about the future level of albacore catches taken by the TLL, noting those SPA catches would vary dependent upon the BET MP output. These assumptions are described below. The impact of alternative catch assumptions are explored in a series of sensitivity tests. In this way, mixed fishery considerations are included in the evaluations.

2 Management strategy evaluation framework

Full details of the management strategy evaluation (MSE) framework, including the operating models (OMs) can be found in WCPFC-SMD02-2024/SMD02-BP-02 (Scott et al., 2024b). A summary of the main assumptions, including a description of the OMs, can be found in the Appendices.

Fisheries operating in the EPO (excluding the overlap) and WCPFC-CA 0-10S areas of the OMs are not managed through the SPA MP. The SPA MP therefore defines the level of fishing of longline and troll fisheries in the WCPFC-CA, south of 10S, and adjusts that level as needed to achieve management objectives.

To run the SPA candidate MP evaluations two key assumptions that need to be made are the level of future albacore catch in the EPO and the WCPFC-CA 0-10S areas. For the evaluations presented here, the future catches in these areas are fixed at the approximate average levels in the years 2014-2023:

- Future level of albacore catch in the 0-10S area of WCPFC-CA (the TLL fishery) is fixed at 9000 mt.
- Future level of albacore catch in the EPO area (excluding the overlap) is fixed at 18,000 mt.

Note that the 18,000 t in the EPO area is less than the level of 22,500 mt used in the evaluations

presented to WCPFC21 (SPC-OFP, 2024).

Sensitivity tests are performed whereby candidate MPs are tested against alternative future catch levels in these two areas. As the adoption of an SPA MP is conditional upon the assumptions made about future catches in these areas, catches in these regions will need to be monitored as part of the SPA MP monitoring strategy to determine if these assumptions are still valid.

Under the WCPFC harvest strategy approach, fisheries operating in archipelagic waters are not managed through an MP. Using the most recently available data, the proportion of SPA catch taken in archipelagic waters in the WCPFC-CA is calculated to be less than 1% of the total SPA WCPFC-CA catch. Excluding fisheries operating in archipelagic waters from MP management in the MSE simulations would require some technical work and a number of assumptions to be made. Given the small proportion of catches in archipelagic waters, and the negligible impact they will have on the performance of the candidate MPs, in the current MP evaluations fisheries operating in archipelagic waters are still under MP control. Following implementation of an MP for SPA, the level of catch in archipelagic waters would be monitored within the monitoring strategy.

3 Candidate management procedures

An MP comprises three components:

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

For each candidate MP examined in this paper 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 key assumptions for the MPs are:

- All fisheries in the WCPFC-CA, south of 10S, are managed either through the setting of catch or effort limits, depending on the candidate MP, i.e. all are managed through catch limits, or all are managed through effort limits.
- The HCR of each MP outputs a scalar that is applied to the baseline catch or effort. Associated catch limits are shown for the catch-based MPs.
- The current baseline for each HCR is the average catch or effort in the period 2020-2022 within the WCPFC-CA, south of 10S, i.e. an output scalar of 1 sets the catch or effort limit for the next management period to the average of 2020-2022 catches or effort.
- 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.

The evaluations assume that the output of an MP will be either the total annual catch or total

annual effort of longline and troll fisheries in the WCPFC-CA south of 10S, for the next 3 year management period, dependent upon the MP. Allocation of that total, and how those allocations are managed in practice (e.g. through effort if the allocation is in terms of catch, or catch if the allocation is in terms of effort) is external to the MP.

Following discussions and feedback from members at SMD02 and WCPFC21 there are currently 4 candidate MPs. The candidate MPs are split into two groups: those that define total future fishing level through setting catch limits and those that do so through setting effort limits.

3.1 Estimation method

The estimation method (EM) is an age-structured production model, implemented in Multifan-CL, with two index fisheries: a longline index in the WCPFC-CA model region and a longline index in EPO model region. This is an update to that presented to SC20 as it has removed the reliance on a WCPFC-CA troll fishery index which helps to 'future proof' the MP (Scott et al., 2024a,b). The updated EM performs well (SPC-OFP, 2024).

Following discussion at SC20 and SMD02, the HCR input is a relative measure of stock status: mean estimated $SB/SB_{F=0}$ in the last three years relative to the mean estimated $SB/SB_{F=0}$ in 2017-2019. The absolute measure of HCR input (mean estimated $SB/SB_{F=0}$ in the last three years) that was also presented to SMD02 has been dropped.

$SB/SB_{F=0}$ 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.

3.2 Harvest control rules

The catch-based candidate MPs have 3 basic HCR shapes (HCRs 7, 10 and 13) and the effort-based candidate MP has one basic HCR shape (HCR 9) (Figure 1, Table 1). Each HCR has a similar shape to the HCR in the adopted interim skipjack MP, with a 'Hillary step' (WCPFC, 2022). The HCR parameters for the catch-based MPs are different to the HCR for the effort-based MP as performance is affected by the management method (catch or effort).

Table 1: Parameter values of the HCR shapes.

HCR		Limit	Step start	Step end	Maximum
Catch-based MPs					
HCR 7	Relative SB/SBF=0	0.37	0.94	1.29	1.59
	HCR output	0.2	1.05	1.05	1.25
	Catch output	10550	55370	55370	65920
HCR 10	Relative SB/SBF=0	0.45	0.93	1.52	1.88
	HCR output	0.2	1.31	1.31	1.51
	Catch output	10550	69090	69090	79630
HCR 13	Relative SB/SBF=0	0.33	0.95	1.15	1.43
	HCR output	0.2	0.82	0.82	1.02
	Catch output	10550	43510	43510	54060
Effort-based MPs					
HCR 9	Relative SB/SBF=0	0.45	0.85	1.09	1.88
	HCR output	0.2	1.46	1.46	1.66

The HCRs have been designed to achieve performance in terms of long-term $SB/SB_{F=0}$, e.g. HCR 7 (catch-based) achieves approximately the same long-term $SB/SB_{F=0}$ as the iTRP, under baseline assumptions for future EPO and TLL catch levels (Table 2). The HCRs can continue to be tuned and refined to better achieve their objectives.

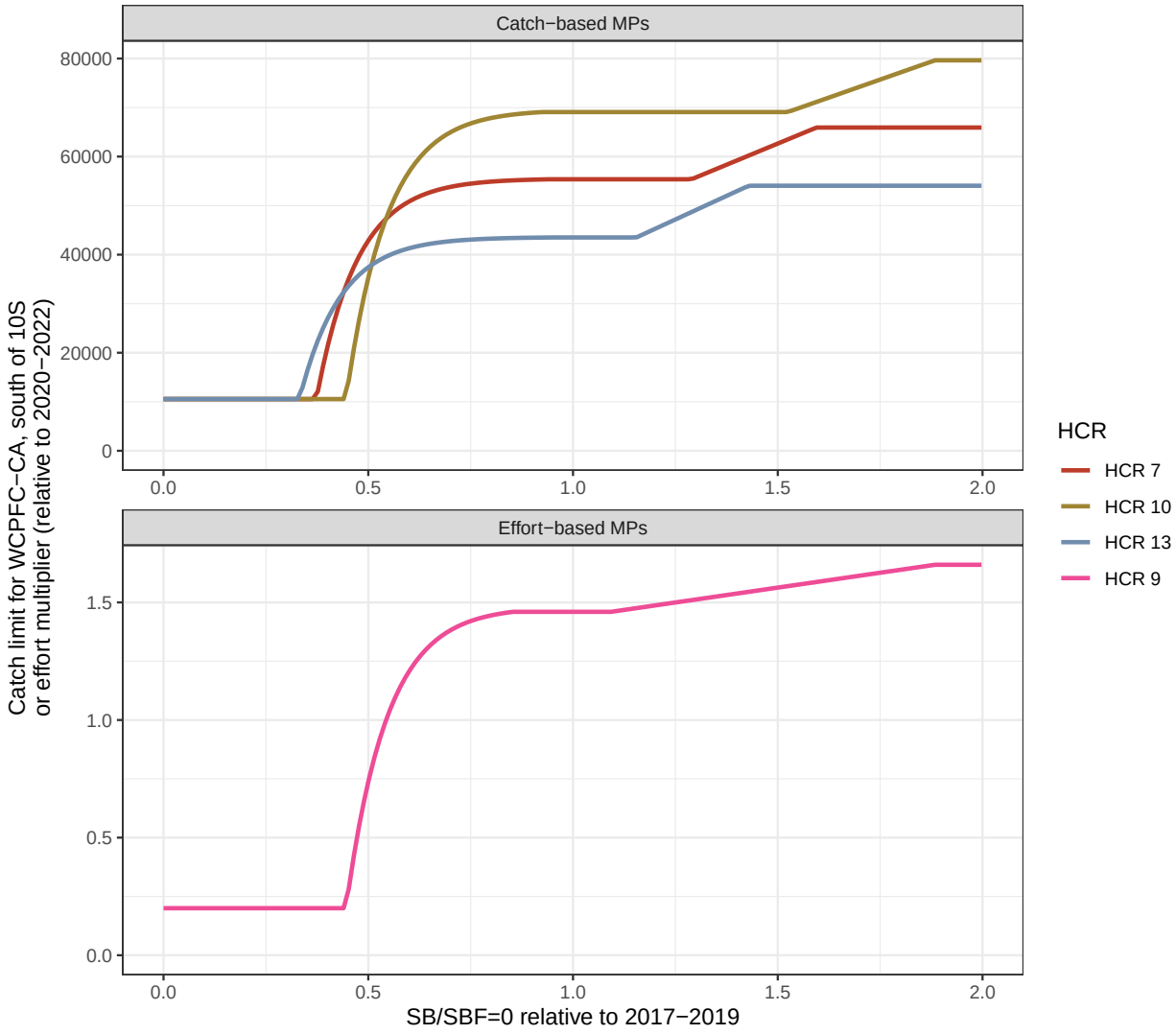

Figure 1: The basic HCR shapes. The MPs are split into two groups based on management output: catch- or effort-based. The input to the HCR is the mean $SB/SB_{F=0}$ of the last three years relative to 2017-2019. The output is a scalar applied to 2020-2022 levels of catch or effort, depending on the MP. For catch-based MPs, the associated catch limit for WCPFC-CA, south of 10S is also shown in mt.

3.3 Meta-rules and constraints

The candidate MPs have constraints on how much the output of the HCR can change between management periods. Results presented in 2024 suggested that alternative constraint options had only a limited impact on the long-term results. As such, only a single constraint option is currently evaluated for each HCR (Table 2). An additional constraint option is evaluated as a sensitivity test.

The first time the MP is used (in 2025), the constraint is applied to the catch or effort in 2023 (assuming a two year data lag), i.e. the catch or effort limit set by the MP for 2026 cannot change by more than X% from the catch or effort level in 2023. The assumed levels of catch or effort in 2023 can therefore impact the performance of an MP with a constraint, particularly in the first few management periods.

For the current evaluations the assumed catch or effort in 2023-2025 is set to the average level in 2017-2022. These assumed catch and effort levels are higher than the baseline (2020-2022) catch and effort.

Table 2: The constraint options for the candidate MPs, and their overall long-term objective under baseline EPO and TLL catch assumptions (18,000 mt EPO and 9000 mt TLL).

HCR shape	Constraint	Objective under baseline assumptions
Catch-based MPs		
HCR 7	+10 -5%	iTRP
HCR 10	+10 -5%	Lower TRP range
HCR 13	+10 -5%	Upper TRP range
Effort-based MPs		
HCR 9	+-5%	Lower TRP range

4 Performance indicators

Six performance indicators (PIs) are calculated. Note that the biomass indicators ($SB/SB_{F=0}$, probability of being above the LRP) are based on the biomass in WCPFC-CA, whereas the catch and effort indicators are based on the area in which the SPA MP operates, i.e. the WCPFC-CA, south of 10S.

- $SB/SB_{F=0}$ 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 (iTRP) and any proposed alternative TRPs.

- Probability of the stock status in the WCPFC-CA 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, south of 10S.
- Vulnerable biomass available to longline fisheries in the WCPFC-CA, south of 10S. This is a proxy for CPUE and is calculated as relative to the average vulnerable biomass in the period 2020-2022.
- Catch variability, calculated as the absolute annual difference in WCPFC-CA catch, south of 10S.
- Effort variability, calculated as the absolute annual difference in WCPFC-CA longline effort, south of 10S, measured in 100s of hooks (as requested by SMD02).

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

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

5 Results

800 stochastic 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 parameters implying a less productive stock, and high fishing pressure. In these cases, the expected catch, effort and stock status for the remainder of the simulation are set to zero.

A brief summary of the results is presented here using box plots in the three different time periods. The larger the box and the longer the whiskers, the greater the uncertainty in the expected values.

The main results include the baseline scenarios for future EPO and TLL catches (18,000 mt and 9000 mt, respectively). Sensitivity tests for different EPO and TLL future assumptions are shown below.

5.1 Stock depletion and LRP risk

The range of expected $SB/SB_{F=0}$ for each candidate MP can be seen in Figure 2. WCPFC20 agreed an interim TRP (iTRP) 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 are shown as the top three horizontal dashed lines, the middle line being the iTRP. Note that these values were proposed on the basis of projections based on the 2024 stock assessment grid. The OM grid is different to the stock assessment grid and so the values have been rescaled accordingly. The bottom dashed line is the LRP.

All current candidate MPs have a probability of being above the LRP greater than the WCPFC threshold of 0.8. The MP based on HCR 10, which achieves the lower range of the proposed TRP,

shows the lowest probability.

5.2 Longline vulnerable biomass, south of 10S

Vulnerable biomass is a proxy for CPUE (catch rates). The relative vulnerable biomass of longline fisheries in the WCPFC-CA, south of 10S, follows a similar pattern to the $SB/SB_{F=0}$ results (Figure 2). The MP based on HCR 13, which achieves the upper TRP range in the long-term, has the highest vulnerable biomass, but in the short- and medium-term it is not much higher than the MP based on HCR 7. The effort based MP with HCR 9 has the narrowest range of anticipated outcomes.

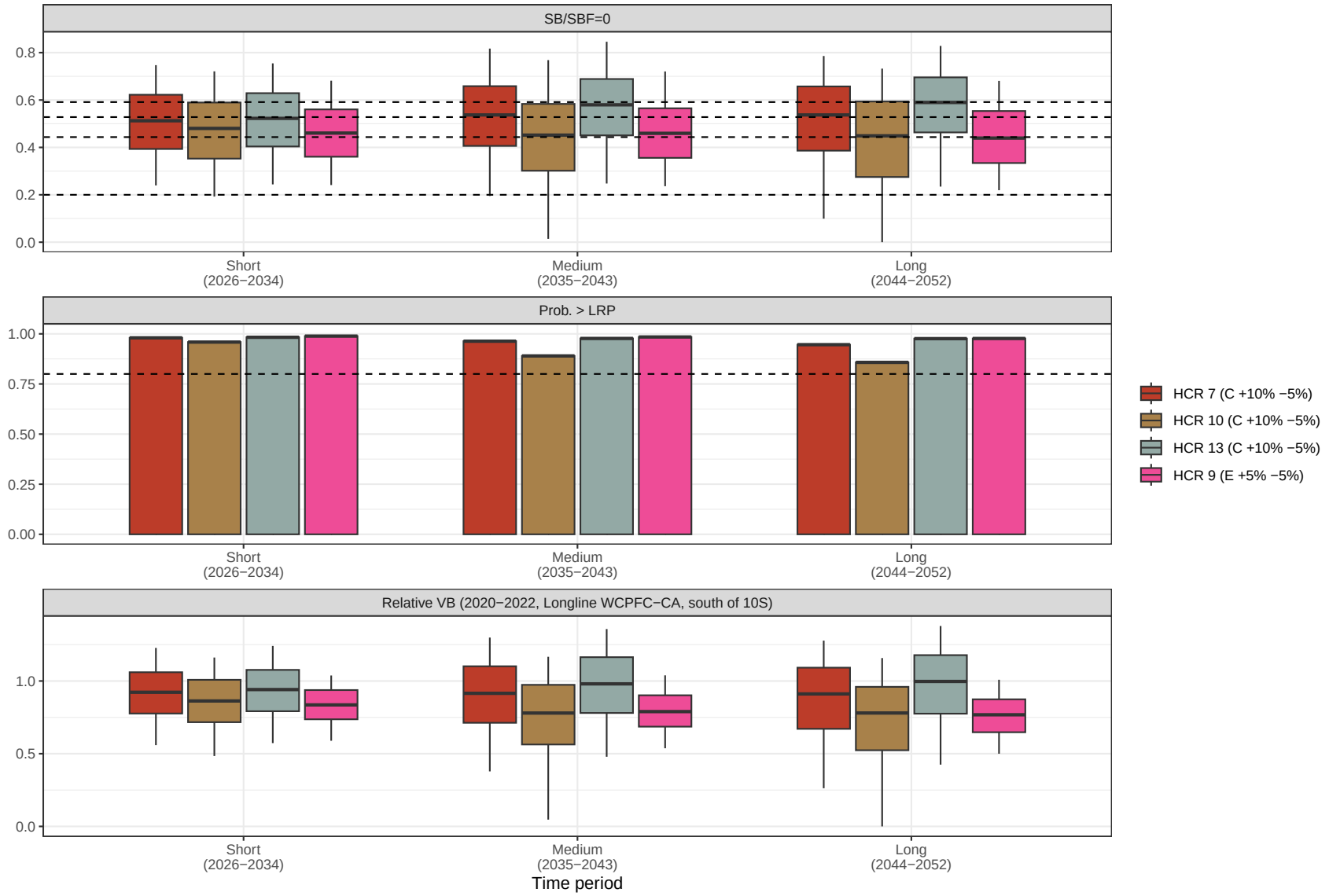

Figure 2: Box plots of $SB/SB_{F=0}$ in the WCPFC-CA and vulnerable biomass for the longline fisheries in the WCPFC-CA, south of 10S, relative to the level in 2020-2022, and a bar plot (middle) of probability of being above the LRP. The whiskers show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. Horizontal lines on the $SB/SB_{F=0}$ plot are the iTRP (second from top), proposed TRPs from WCPFC20 and the LRP (bottom). The horizontal line on the Prob. > LRP plot is at 0.8, the minimum required by WCPFC.

5.3 Expected catches and catch variability

The median level of expected catches are conditional on the shape of the HCR (Figure 3). Only catches in the WCPFC-CA, south of 10S are considered here.

The candidate MP with HCR 13 has the lowest expected catches, and is the only one which has catches lower than the 2020-2022 average level. This MP also achieves the highest level of stock status and vulnerable biomass, an example of the known trade-off between high catches and high CPUE.

Some of the advantages of having a catch-based MP setting can be seen in the low uncertainty in future catches, and also low levels of catch variability. The catch variability for the catch-based MPs will be partially determined by the constraint (here +10% -5%).

The long whiskers seen for the MP based on HCR 10 in the medium- and long-term are a result of the stock crashing in some iterations, due to a combination of high catches, less productive stock assumptions, and low recruitment (Figure 3). For these iterations the catches are set to 0 for the remainder of the simulation. For this MP, only 6% of the 800 iterations resulted in the stock crashing at the end of the time series. However, as the whiskers show the 95th percentile range (almost the full range of results), this is enough to result in the whisker reaching 0. Given that the box in Figure 3 shows the 60th percentile range and is very narrow, the iterations that result in the stock crashing can be thought of as outliers.

The effort-based MP with HCR 9 shows high levels of catch variability. This is because the level of realised catches is a product of the fishing effort and the vulnerable biomass. As biomass levels can vary due to natural processes (here modelled through recruitment variability) as well as fishing pressure, an effort-based MP can therefore result in variable catches, with a high level of uncertainty.

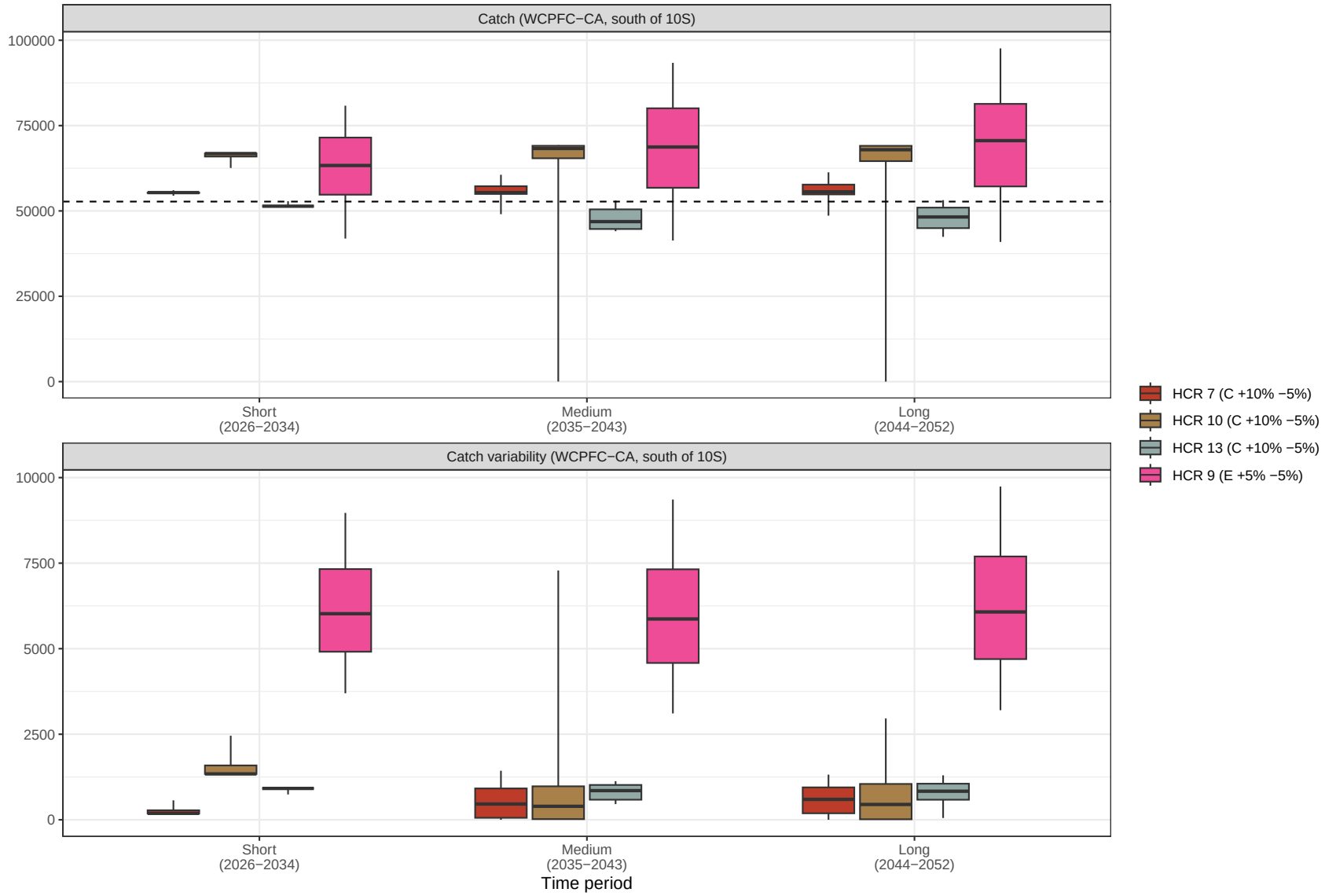

Figure 3: Box plots of total catch in the WCPFC-CA, south of 10S, and associated average annual catch variability (both in mt). The whiskers show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The dashed horizontal line on the catch plot is the HCR baseline, the average catch in 2020-2022 in the WCPFC-CA, south of 10S.

5.4 Effort variability

As seen for catch variability, longline effort variability is strongly affected by the management method (Figure 4).

Catch-based MPs have higher effort variability than effort-based MPs. The amount of effort needed to take a set catch limit depends on the biomass available to the fishery. As noted above, biomass levels vary due to natural processes as well as fishing pressure. Therefore, the amount of effort needed to take a set catch limit varies over time, resulting in higher effort variability for the catch-based MPs.

The whiskers seen in Figure 4 are long for the catch-based MP. The evaluations for the catch-based MPs assumed that the catch limit is always caught where possible, i.e. when there are enough fish. If the stock is very low it can require unrealistically high levels of fishing effort to take the catch limit. In reality the maximum effort would be limited, and the realised catches resulting from that effort would be lower than the catch limit set by the MP. This would greatly limit the effort variability.

As noted above, the output type of the MP is not necessarily how the limit set by the MP will be implemented, e.g. the catch limits specified by a catch-based MP may be implemented through effort limits. To implement a catch limit set by a catch-based MP as an effort limit requires a conversion between catch and effort. This conversion will likely be based on recently observed catch rates. Therefore, the effort limits that would be implemented would be expected to be as stable as the catch limits set by the catch-based MP, and subject to the same constraint on how much the output can change between management periods.

The average long-term effort variability for the effort-based MP with HCR 9 is lower than in the other two periods. The level of variability in that period is, however, less certain, i.e. there is more uncertainty in the expected effort variability. However, the change in effort between management periods is still constrained by the +-5% constraint.

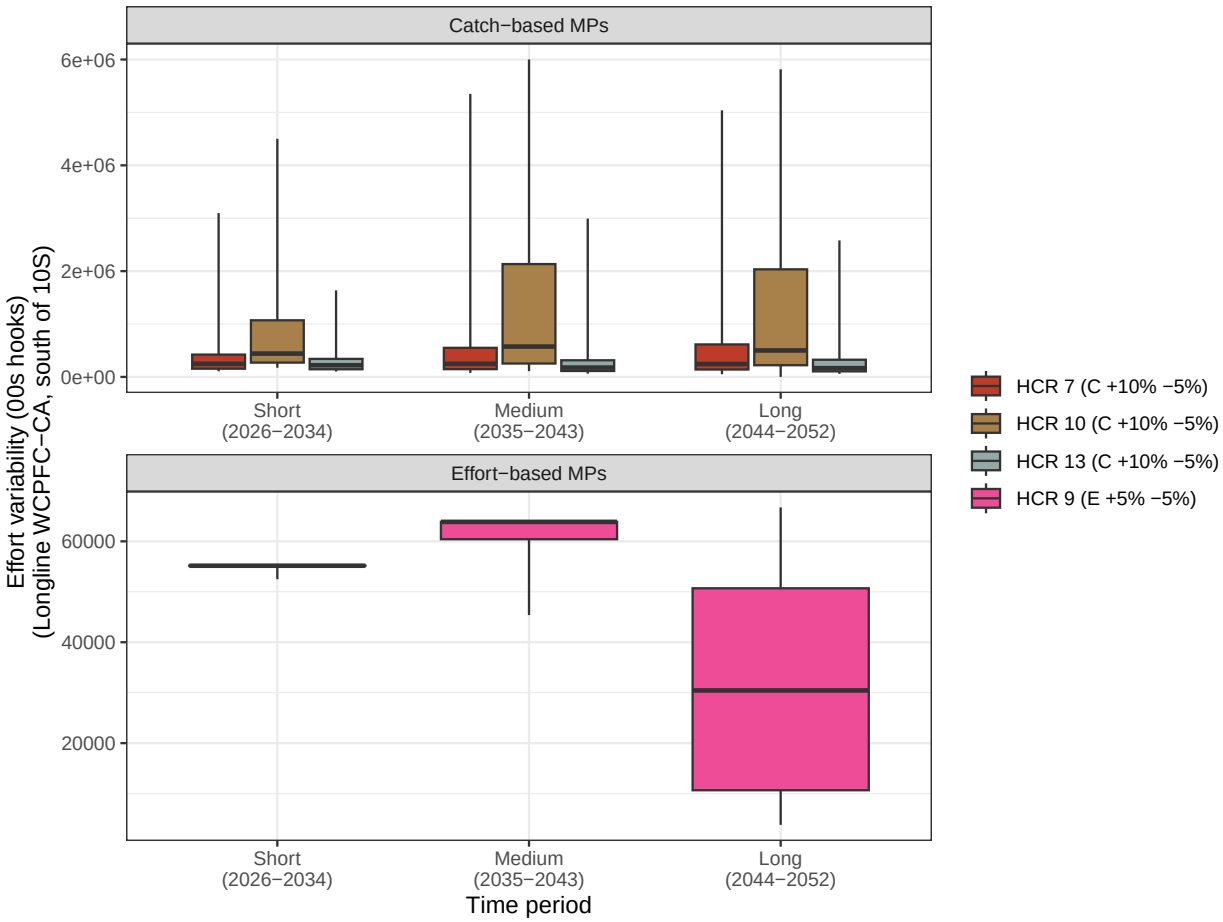

Figure 4: Box plots of average annual WCPFC-CA longline effort variability (00s of hooks), south of 10S. The whiskers show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The plot is presented in two windows as the results from catch- and effort-based MPs have different scales.

5.5 Sensitivity tests

One-off sensitivity tests were performed, including alternative assumptions about the future levels of albacore catches in the EPO and in the region between the equator and 10S in the WCPFC-CA.

These evaluations use a catch-based MP with HCR 7 and a +10% -5% constraint as the base case. The results of the single change are then compared to the results from the base case.

EPO baseline

In the evaluations performed above, the fisheries in the EPO are not managed through the MP and their future catches are fixed at 18,000 mt per annum. In this sensitivity test the future catches in the EPO are fixed at the higher level of 22,500 mt per annum, consistent with the assumptions in SPC-OFP (2024) (Figure 5).

Higher catches in the EPO result in slightly lower expected stock status and vulnerable biomass in the WCPFC-CA. Catches in the WCPFC-CA, south of 10S, are largely unaffected by the increase in catches in the EPO, even though expected biomass is lower, suggesting that the stock status is on the 'Hillary step' part of the HCR, i.e. the stock status is fluctating but is still on the step so that the output catch limit does not change frequently. This demonstrates that the HCR is working as expected.

TLL baseline

In the evaluations performed above the longline fisheries in WCPFC-CA, equator to 10S (tropical longline - TLL), are not managed through the MP and their future catches are fixed at 9,000 mt per annum. Under the mixed fishery approach it is proposed that these fisheries will be managed through the bigeye MP which will not consider the stock status of SPA. It is therefore important that the performance of the SPA MP is robust to future SPA catch levels by the TLL fishery. In this sensitivity test the future catches of the TLL fishery are fixed at a higher level of 12,000 mt per annum (approximately the highest one year catch by the TLL fishery in the last ten years) (Figure 6).

As with the alternative EPO catch scenario above, under the higher TLL catch scenario, the average long-term $SB/SB_{F=0}$ and vulnerable biomass are slightly lower. Also as above, the catches in the WCPFC-CA, south of 10S, are largely unaffected by the increase in catches by the TLL fisheries, suggesting that the stock status is on the 'Hillary step' and the HCR is performing as expected.

EPO and TLL baseline

In this sensitivity test, the future SPA catches of the EPO region and TLL fisheries are both set at higher levels to the baseline (22,5000 mt and 12,000 mt) (Figure 7).

This scenario represents the biggest change from the baseline assumptions about TLL and EPO

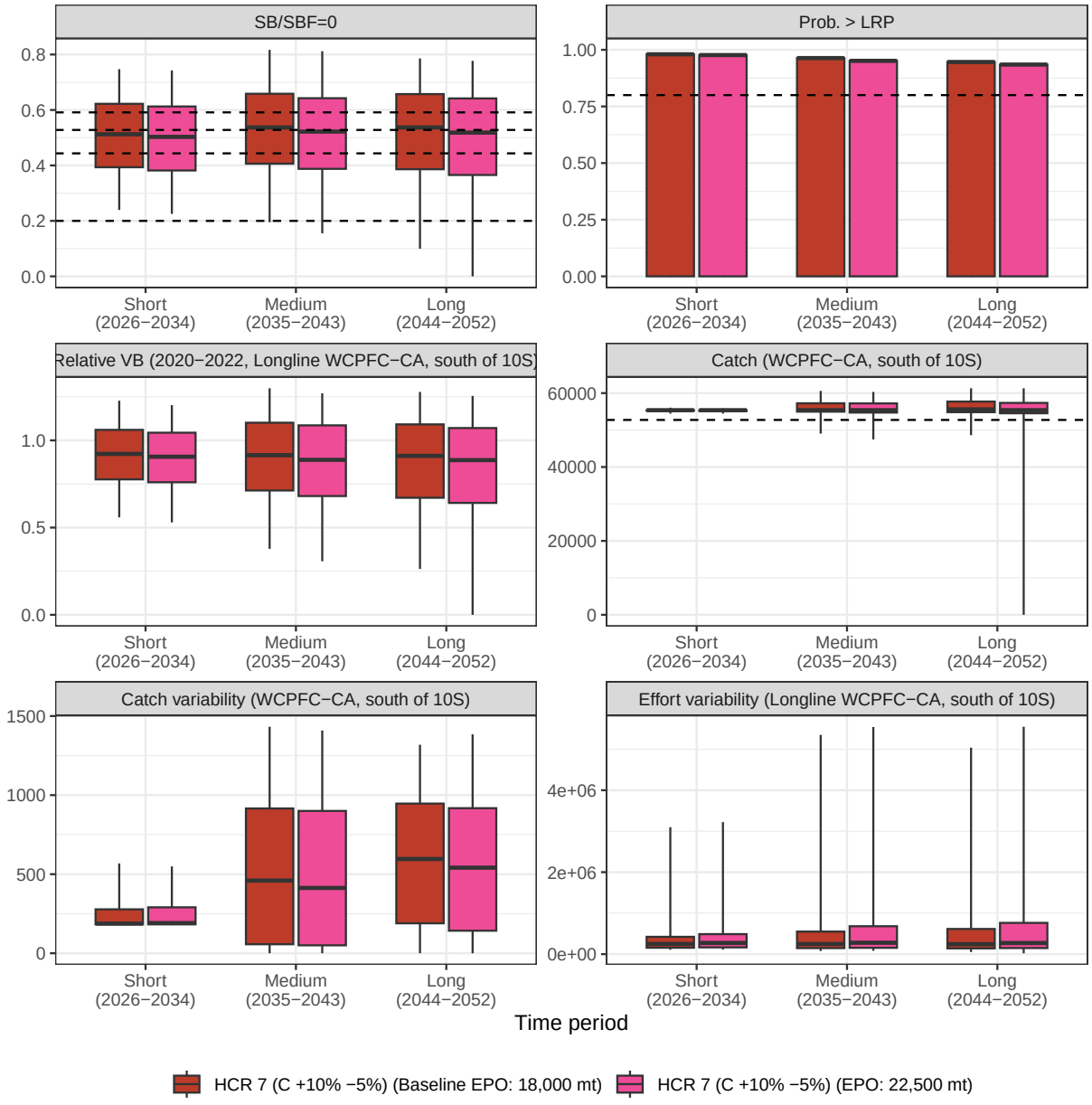

Figure 5: The performance indicators for the same MP where the constant catch level in the EPO is 18,000 mt (baseline) and 22,500 mt. A catch-based MP with HCR 7 is used, with +10% -5% constraint. The whiskers show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The probability of being above LRP is shown as a bar plot.

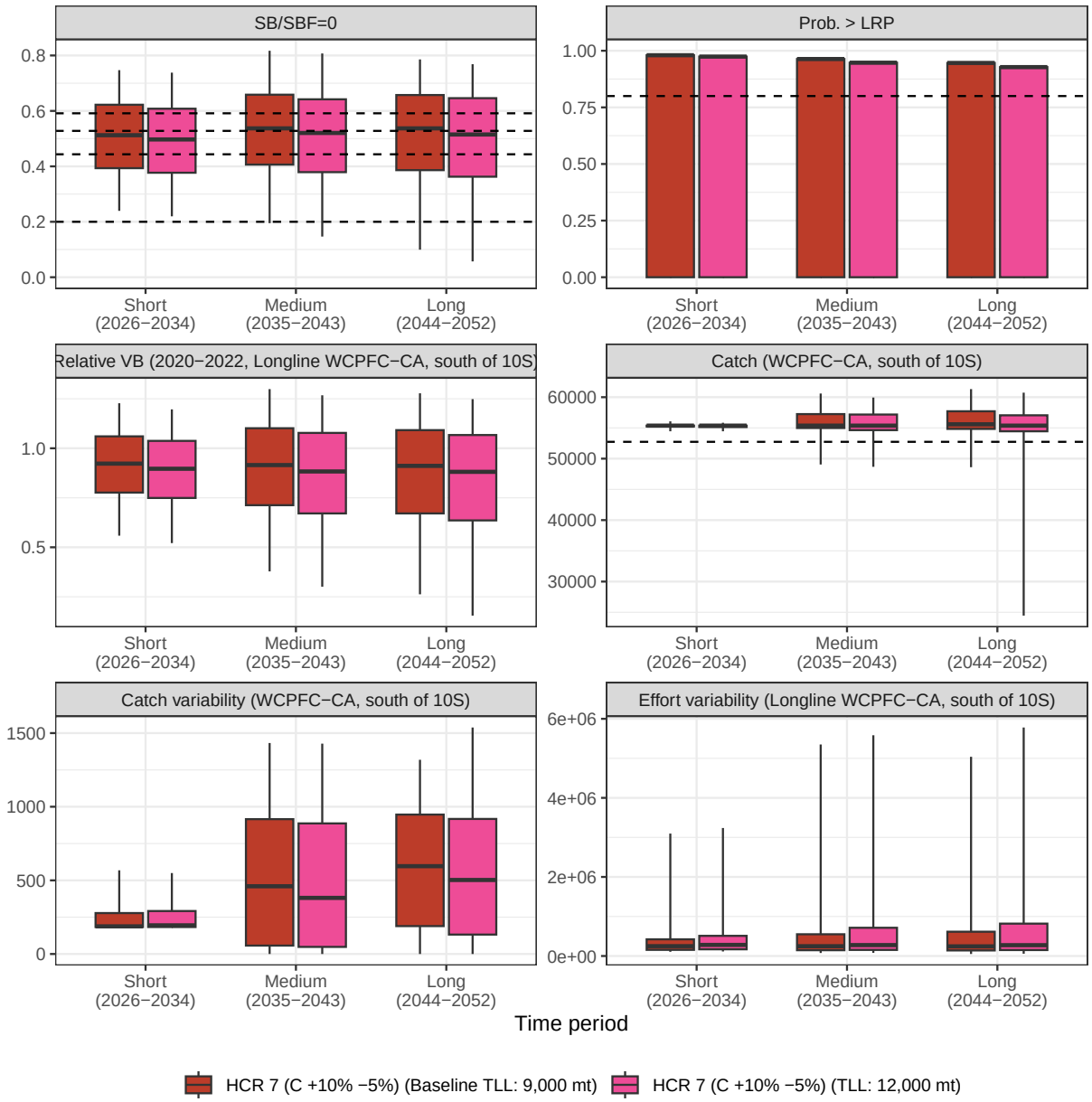

Figure 6: The performance indicators where the constant catch level of the TLL fisheries are 9,000 mt (baseline) and 12,000 mt. A catch-based MP with HCR 7 is used, with +5% -10% constraint. The whiskers show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The probability of being above LRP is shown as a bar plot.

future catches. The average long-term $SB/SB_{F=0}$ is lower than the objective of the iTRP, and the vulnerable biomass (CPUE) is also lower. However, catches in the WCPFC-CA, south of 10S, are largely unaffected and are still higher than the 2020-2022 average.

Alternative constraint

In the main results, the MP with HCR 7 has a constraint of +10% -5%. Here the same HCR is tested but with an alternative constraint of +-10% (Figure 8). Baseline values for future EPO and TLL catches are used. The alternative constraint has little impact on the performance of the MP. The main differences are increased catch variability and slightly less uncertainty in the expected catches with the looser constraint, in the long-term.

For more detail on the potential impact of constraints, see the relevant section in Scott et al. (2024b).

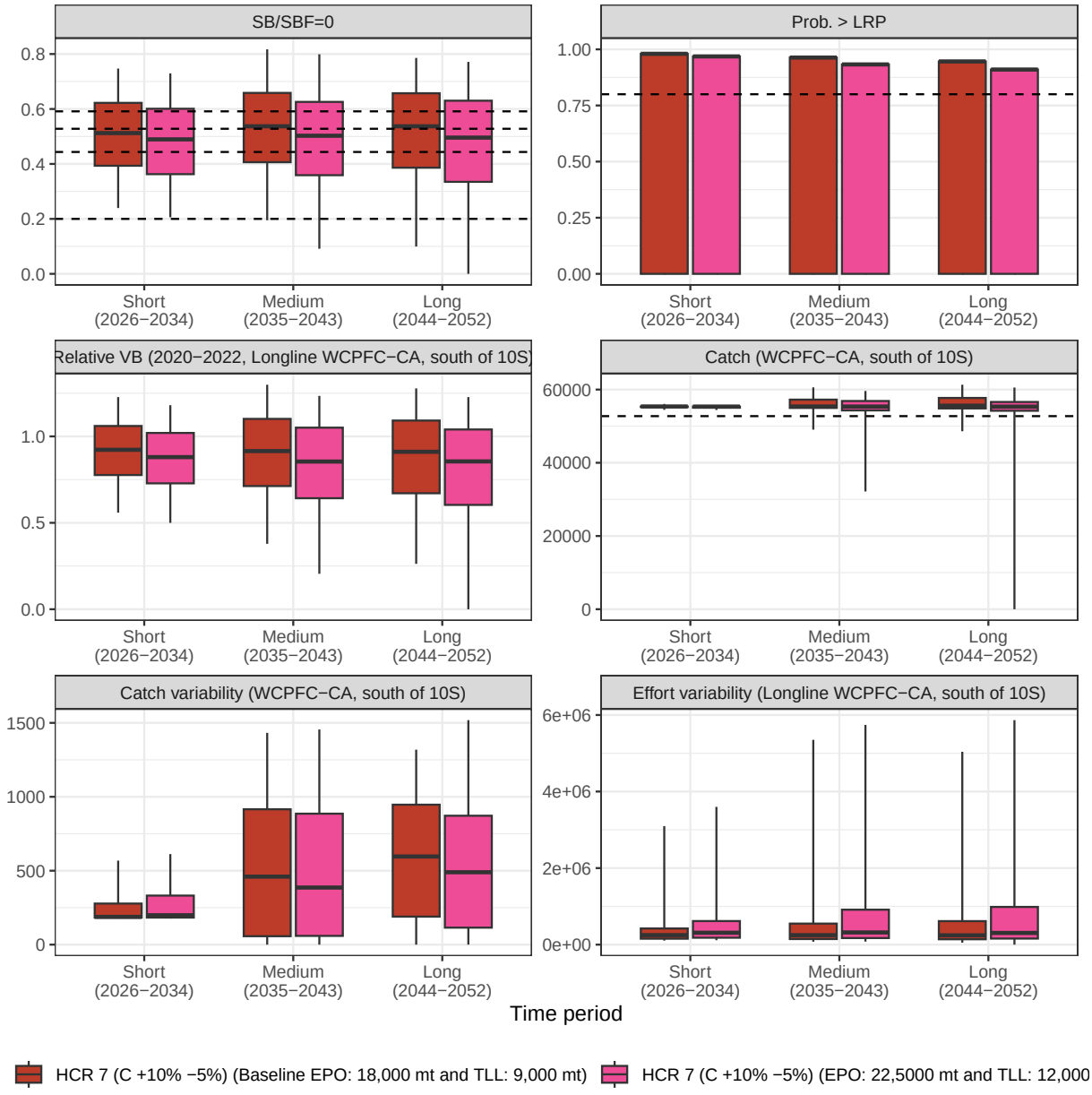

Figure 7: The performance indicators where the constant catch level of the TLL is either 9,000 mt or 12,000 mt and of the EPO region is either 18,000 mt or 22,5000 mt. A catch-based MP with HCR 7 is used, with +5% -10% constraint. The whiskers show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The probability of being above LRP is shown as a bar plot.

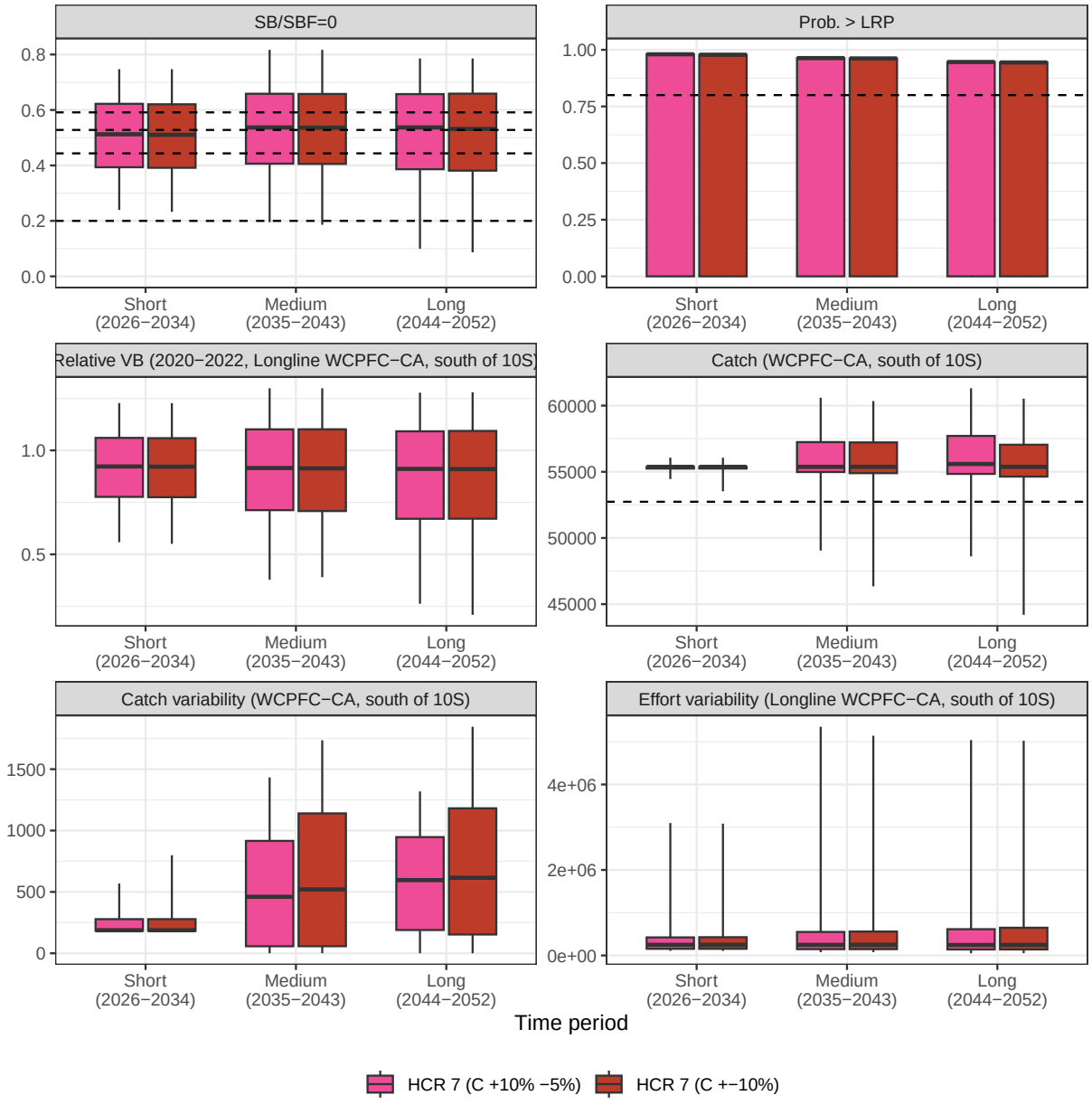

Figure 8: Comparing the performance indicators for two constraint assumptions. A catch-based MP with HCR 7 is used, with +5% -10% constraint, and a +-10% constraint. Baseline values for future EPO and TLL catches are used. The whiskers show the 95th percentile range, the box shows the 60th percentile range, and the horizontal line is the median value. The probability of being above LRP is shown as a bar plot.

5.6 Tables of results

Tables of the median results for the short- and long-term can be seen Table 3 and Table 4.

Table 3: Results of the baseline and sensitivity scenarios in the short-term (2026-2034). The value shown is the median. SB/SBF=0 is shown as relative to the mean SB/SBF=0 in 2017-2019, noting that the iTRP is defined as the mean SB/SBF=0 in 2017-2019 * 0.96.

HCR	EPO	TLL	SB/SBF=0 relative to 2017-2019	Prob. > LRP	Relative VB (longline WCPFC-CA, S of 10S)	Catch (mt) (WCPFC-CA, S of 10S)	Catch variability (mt) (WCPFC-CA, S of 10S)	Effort variability (00s hooks) (longline WCPFC-CA, S of 10S)
Main results								
HCR 7 (C +10% -5%)	18,000	9,000	0.92	0.98	0.92	55,400	188	248,000
HCR 10 (C +10% -5%)	18,000	9,000	0.86	0.96	0.86	66,800	1,340	441,000
HCR 13 (C +10% -5%)	18,000	9,000	0.94	0.98	0.94	51,400	916	221,000
HCR 9 (E +5% -5%)	18,000	9,000	0.83	0.99	0.84	63,300	6,020	55,200
Sensitivity results								
HCR 7 (C +10% -5%)	22,500	9,000	0.90	0.98	0.91	55,400	191	272,000
HCR 7 (C +10% -5%)	18,000	12,000	0.89	0.97	0.90	55,400	195	280,000
HCR 7 (C +10% -5%)	22,500	12,000	0.88	0.97	0.88	55,400	199	311,000
HCR 7 (C +-10%)	18,000	9,000	0.92	0.98	0.92	55,400	188	249,000

Table 4: Results of the baseline and sensitivity scenarios in the long-term (2044-2052). The value shown is the median. SB/SBF=0 is shown as relative to the mean SB/SBF=0 in 2017-2019, noting that the iTRP is defined as the mean SB/SBF=0 in 2017-2019 * 0.96.

HCR	EPO	TLL	SB/SBF=0 relative to 2017-2019	Prob. > LRP	Relative VB (longline WCPFC-CA, S of 10S)	Catch (mt) (WCPFC-CA, S of 10S)	Catch variability (mt) (WCPFC-CA, S of 10S)	Effort variability (00s hooks) (longline WCPFC-CA, S of 10S)
Main results								
HCR 7 (C +10% -5%)	18,000	9,000	0.96	0.95	0.91	55,600	596	243,000
HCR 10 (C +10% -5%)	18,000	9,000	0.81	0.86	0.78	67,900	448	500,000
HCR 13 (C +10% -5%)	18,000	9,000	1.06	0.98	1.00	48,200	834	166,000
HCR 9 (E +5% -5%)	18,000	9,000	0.79	0.98	0.77	70,600	6,070	30,400
Sensitivity results								
HCR 7 (C +10% -5%)	22,500	9,000	0.93	0.93	0.89	55,400	541	271,000
HCR 7 (C +10% -5%)	18,000	12,000	0.92	0.93	0.88	55,400	503	274,000
HCR 7 (C +10% -5%)	22,500	12,000	0.89	0.91	0.86	55,300	490	306,000
HCR 7 (C +-10%)	18,000	9,000	0.95	0.94	0.91	55,400	615	247,000

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Appendix: Main assumptions behind the SPA MSE framework

The MSE framework is described in WCPFC-SMD02-2024/SMD02-BP-02 (Scott et al., 2024b).

The key difference to those assumptions is that the SPA MP no longer applies to fisheries operating in the equator to 10S region of the WCPFC-CA. Instead the future catches of SPA in the equator to 10S region are fixed at 9000 mt per annum (approximate the average of 2014 to 2023 catches). Additionally, the future catches of fisheries operating in the EPO region of the model are fixed at 18,000 mt per annum (approximate the average of 2014 to 2023 catches)

Main MSE assumptions

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 evaluations where the MP sets catch limits, the catches for all fisheries in the WCPFC-CA in the period 2023-2025 are set to the average of their 2017-2022 levels.
- For the evaluations where the MP sets effort limits, the effort 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 equally to all fisheries (longline and troll) operating within the WCPFC-CA, south of 10S.
- The catch or effort limits specified by the MP are always fully utilised (if possible), i.e. there is no implementation error.
- The MP does not apply to fisheries operating in the EPO region of the model, unless otherwise specified.
- The total future catches of fisheries operating in the EPO region of the model are fixed at 18,000 mt per annum.
- The MP does not apply to fisheries operating in the equator to 10S region of the WCPFC-CA.
- The total future catches of fisheries operating in the equator to 10S region of the WCPFC-CA are fixed at 9000 mt per annum.

Operating models

The operating model (OM) grid is based on the 2024 South Pacific wide stock assessment, with additional uncertainty scenarios (Scott et al., 2024c; 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. Note that the inclusion of effort creep in the simulations has been improved since SMD02. A factorial combination of these factors gives 800 OMs.

The fisheries managed through the MP (i.e. those in the WCPFC-CA, model area 1, south of 10S) are managed either through setting catch limits or effort limits, depending on the MP being evaluated.

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.

Appendix: Estimation method settings

Following the update presented in SPC-OFP (2024), the esimation method now only uses two index fisheries: the longline indices in the WCPFC-CA and the EPO. The troll index has been removed. This removes the reliance on the troll index and helps to 'future proof' the MP. This change was not found to impact the performance of the esimation method. The estimation method and CPUE standardisation settings can be seen in Table 5 and Table 6.

Table 5: Settings for the estimation method

Model setting	Value
Regional structure	2 regions
Number of fisheries	19
Longline	13
Troll / Driftnet	4
Index	2 (longline only)
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

Table 6: Model settings and post-processing steps used in the CPUE standardisation for south Pacific albacore estimation method.

Model Setting	Description
Model Type	Spatiotemporal delta-gamma generalized linear mixed model (delta-GLMM).
Spatial Knot Configuration	A mesh with 166 spatial knots.
Model Equations	$$y_i \sim \text{Bernoulli}(p_i)$$ $$\log\left(\frac{p_i}{1-p_i}\right) = \text{Year}_i + \omega_1(s_i) + \varepsilon_1(s_i, t_i) + s(\text{HBF}_i) + \text{Flag}_i + \beta_1$$ $$c_i \sim (\log \mu_i, \sigma^2, \theta_i^2)$$ $$\log \mu_i = \text{Year}_i + \omega_2(s_i) + \varepsilon_2(s_i, t_i) + s(\text{HBF}_i) + \text{Flag}_i + \beta_2$$ where θ is the coefficient of variation for positive catch rate measurement errors, y is the encounter probability, c is the CPUE, and i indexes individual records. *Year* is the year effect; ω is the spatial random effect at location x; ε is the spatiotemporal random effect at location x and time t; $s(HBF)$ is a spline function for hook-based fishing effort; and *Flag* is the additive effect of the flag group. The spatial variation terms $\omega_2(x_i)$ are modeled as a Gaussian random field with a Matérn covariance function to account for spatial autocorrelation.
HBF Imputation	Missing HBF values are predicted using a random forest approach (Breiman, 2001) implemented via the `randomForest` R package (Liaw and Wiener, 2002). The model uses predictors including year, month, latitude, longitude, number of hooks fished, vessel flag, the proportional catch of the four main species (albacore, yellowfin, bigeye, swordfish), and total catch value, with 500 trees.
Implementation Platform	`sdmTMB` version 0.3.0 (R package).
Normalisation Method	CPUE values are mean-centered using absolute values.
Penalty Term Calculation	Penalty terms are applied as the coefficient of variation (CV) for the catch-conditioned model.