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Example Performance Metrics and Associated Plots for the Pacific Bluefin Tuna Management Strategy Evaluation

Desiree Tommasi[a,b] and Huihua Lee[a]

a: Fisheries Resources Division, NOAA Fisheries, Southwest Fisheries Science Center, La Jolla, CA, USA
b: Institute of Marine Sciences, University of California Santa Cruz, Santa Cruz, CA, USA

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Summary

We present potential plots that could be used to summarize the performance metrics agreed upon by the Inter American Tropical Tuna Commission (IATTC) and Western and Central Pacific Fisheries Commission of the Northern Committee (WCPFC NC) Joint Working Group (JWG) on Pacific Bluefin tuna (PBF) management for the PBF Management Strategy Evaluation (MSE).

Introduction

The two Regional Fisheries Management Organizations (RFMOs) tasked with managing the PBF stock, WCPFC NC and IATTC, requested, via the JWG, that the ISC PBF working group develop an MSE to help inform development of a long-term management strategy for PBF once the stock is rebuilt to the second rebuilding target of 20%SSB0 (JWG 2022). As part of the MSE process the JWG defined a set of management objectives and associated performance metrics with which to evaluate performance of the candidate harvest control rules put forward by the JWG and run with the MSE simulation framework (WCPFC 2023).

Output of MSE is voluminous given the multiple iterations, uncertainty scenarios, and harvest control rules. It is important to clearly summarize results for the performance metrics of interest to stakeholders across the many simulations to maximize utility and uptake of MSE results. The aim of this paper is to demonstrate potential summary plots for the performance metrics (Table 1) put forward by the PBF JWG using a set of preliminary simulations.

Table 1. List of operational management objectives and performance metrics for Pacific Bluefin tuna agreed upon during JWG08. SSB refers to female spawning stock biomass, LRP to limit reference point. F is the fishing intensity (1-SPR) and F_{target} is the target reference point.

Category	Operational Management Objective	Performance Metric
Safety	There should be a less than 20% probability of the stock falling below the LRP	Probability that SSB< LRP in any given year of the evaluation period
Status	To maintain fishing mortality at or below F_{target} with at least 50% probability	Probability that $F \le F_{target}$ in any given year of the evaluation period

		Probability that SSB is below the equivalent biomass depletion levels associated with the candidates for F_{target}
Stability	To limit changes in overall catch limits between management periods to no more than 25%, unless the ISC has assessed that the stock is below the LRP	Percent change upwards in catches between management periods excluding periods when SSB<LRP Percent change downwards in catches between management periods excluding periods when SSB<LRP
Yield	Maintain an equitable balance in proportional fishery impact between the WCPO and EPO	Median fishery impact (in %) on SSB in the terminal year of the evaluation period by fishery and by WCPO fisheries and EPO fisheries
	To maximize yield over the medium (5-10 years) and long (10-30 years) terms, as well as average annual catch yield from the fishery.	Expected annual yield over years 5-10 of the evaluation period, by fishery. Expected annual yield over years10-30 of the evaluation period, by fishery. Expected annual yield in any given year of the evaluation period, by fishery.
	To increase average annual catch in all fisheries across WCPO and EPO	Expected annual yield in any given year of the evaluation period

Methods

To develop plots for the performance metrics we use the output of 24,000 simulations for 100 iterations, 20 operating models (OMs, i.e. uncertainty scenarios), and the 12 candidate HCRs put forward by the JWG run with no estimation error. The simulations were run for an evaluation period of 22 years. The simulations used a constant selectivity set at the 2015-2022 average, a relative F also set to the 2015-2022 baseline, and are the same as those outlined in Tommasi and Lee 2024, but without OM8. Results are presented across the 20 OMs to capture the parameter uncertainty and each OM is weighted equally.

Results and Discussion

Safety Performance Metric

Figure 1 shows output by HCR for the safety performance metric, the "Probability that SSB< LRP in any given year of the evaluation period", so a lower probability is best. This was computed for each HCR by counting the number of times across iterations, evaluation years, and OMs that SSB was below the LRP relative to the total number of iterations, evaluation years, and OMs. All HCRs have a probability of breaching their own LRP less than 20% (Fig. 1). HCRs 1 to 5 have the highest probabilities as they have the highest LRPs of 20% $SSB_{F=0}$ or 15% $SSB_{F=0}$ (Fig. 1).

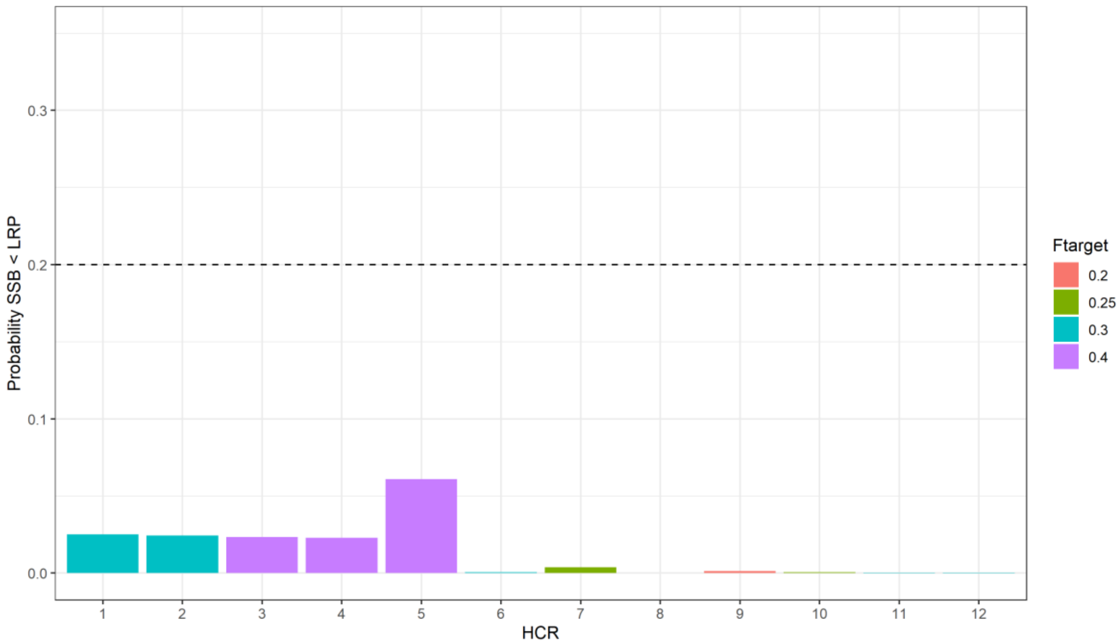

Figure 1. Probability that SSB is less than the LRP for each candidate HCR across 100 iterations, 20 OMs, and the 22-year evaluation period. Bar colors represent the F_{target}

associated with each HCR and the dotted line the probability level in the management objective.

To compare HCR performance against a common biomass threshold, we also compute the probability of SSB<20% $SSB_{F=0}$. 20% $SSB_{F=0}$ is the second rebuilding target. Here we note that the worst performing HCRs are those with the lowest F_{target} reference point (Fig. 2). Nevertheless, all HCRs have a probability of breaching the rebuilding target that is less than 20%.

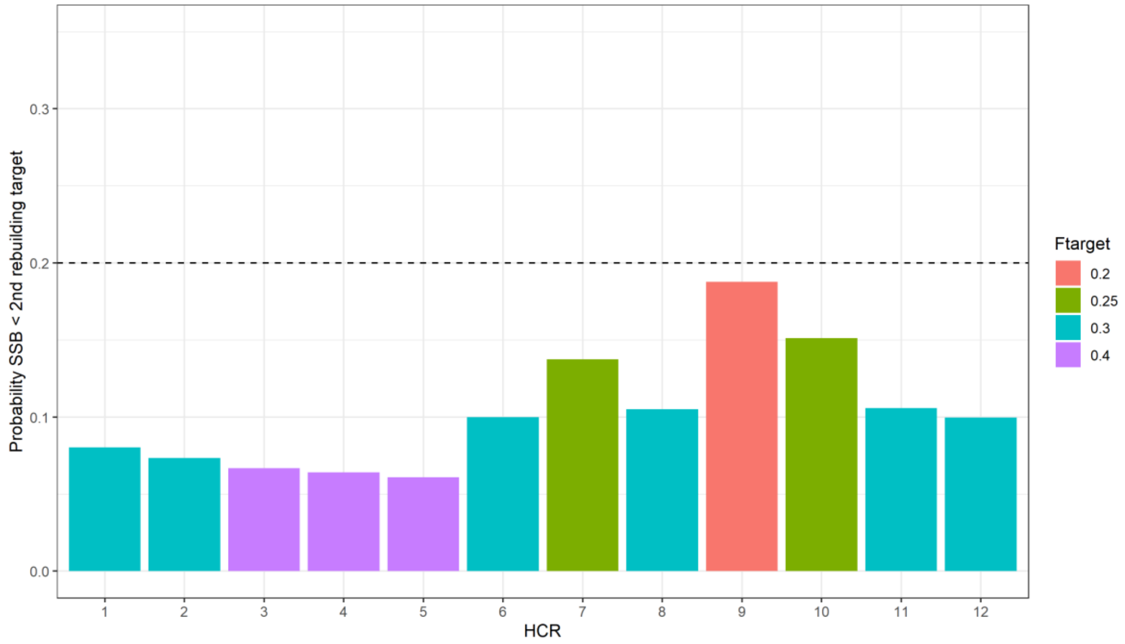

Figure 2. Probability that SSB is less than the LRP for each candidate HCR across 100 iterations, 20 OMs, and the 22-year evaluation period. Bar colors represent the F_{target} associated with each HCR and the dotted line the probability level in the management objective.

The safety performance metric depends on the mean SSB level achieved during the simulation as well as its variability. We note that HCRs 7, 9, and 10 have the lowest median SSB (Fig. 3) and thus a higher probability of breaching the second rebuilding target.

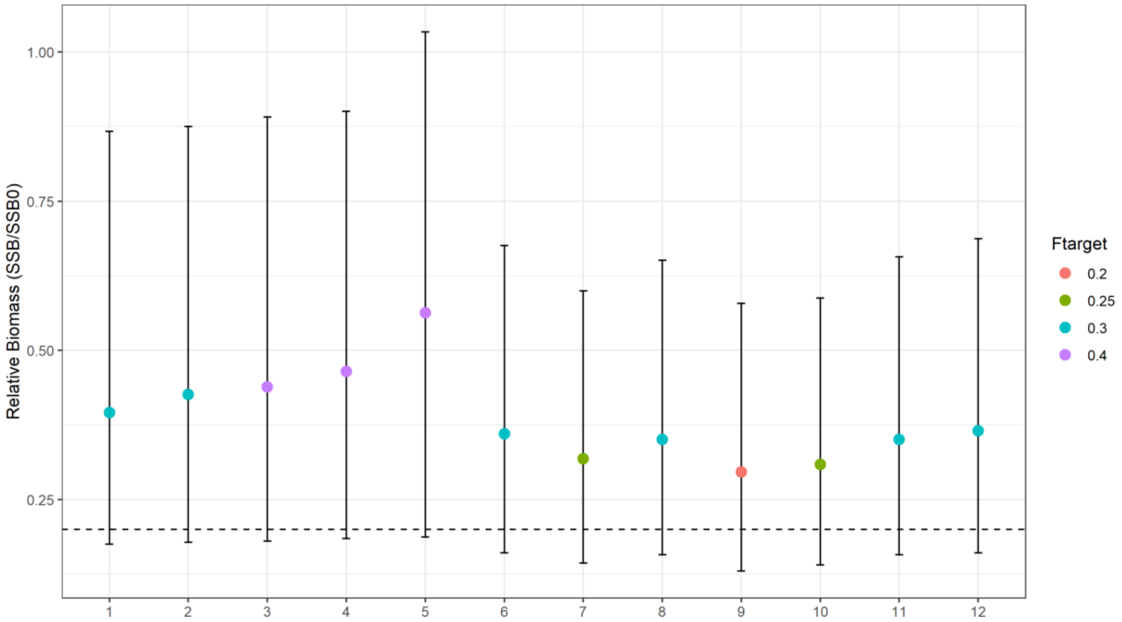

Figure 3. Median (dots) and 5th to 95th quantiles (error bars) of SSB relative to unfished for each HCR across 100 iterations, 20 OMs, and the 22-year evaluation period.

Status Performance Metrics

Figure 4 shows output by HCR for the first status performance metric, the "Probability that $F \leq F_{target}$ in any given year of the evaluation period", so a higher probability is best. This was computed for each HCR by counting the number of times across iterations, evaluation years, and OMs that F, measured as 1-SPR where SPR is the spawning potential ratio, was below the F_{target} relative to the total number of iterations, evaluation years, and OMs. All HCRs have a probability of being lower or equal to their F_{target} that is well above 50% (Fig. 4). This is because F only slowly increases to the F_{target} across the evaluation period due to the 25%TAC increase limit (see Tommasi and Lee 2024). Therefore, for most HCRs, the median F remains well below the F_{target} (Fig. 5).

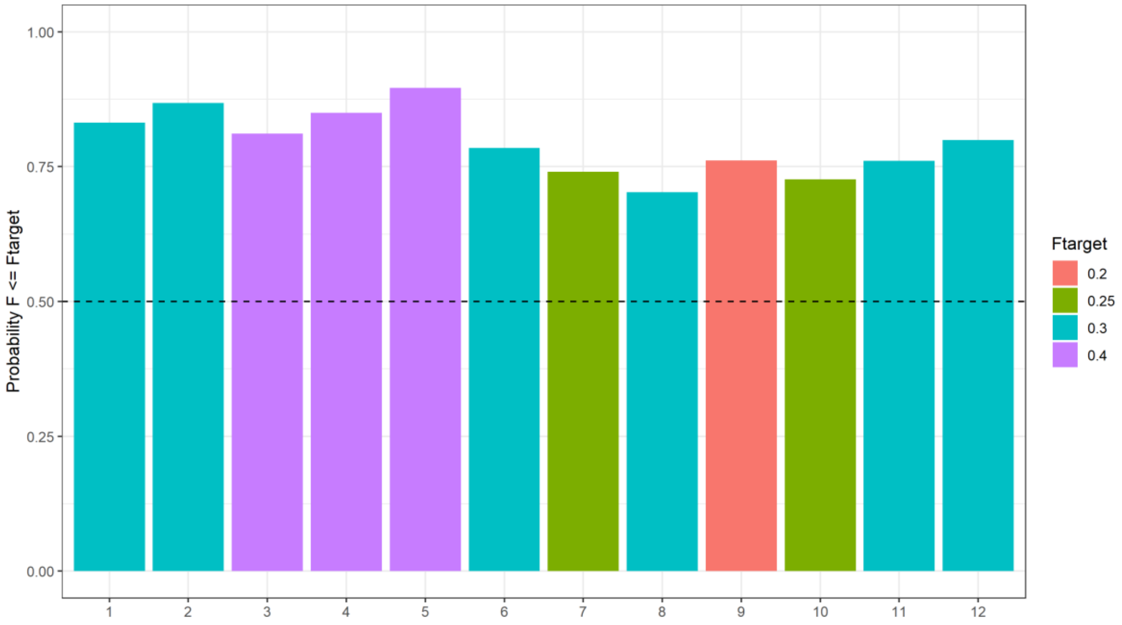

Figure 4. Probability that F is less or equal to the F_{target} for each candidate HCR across 100 iterations, 20 OMs, and the 22-year evaluation period. Bar colors represent the F_{target} associated with each HCR and the dotted line the probability level in the management objective.

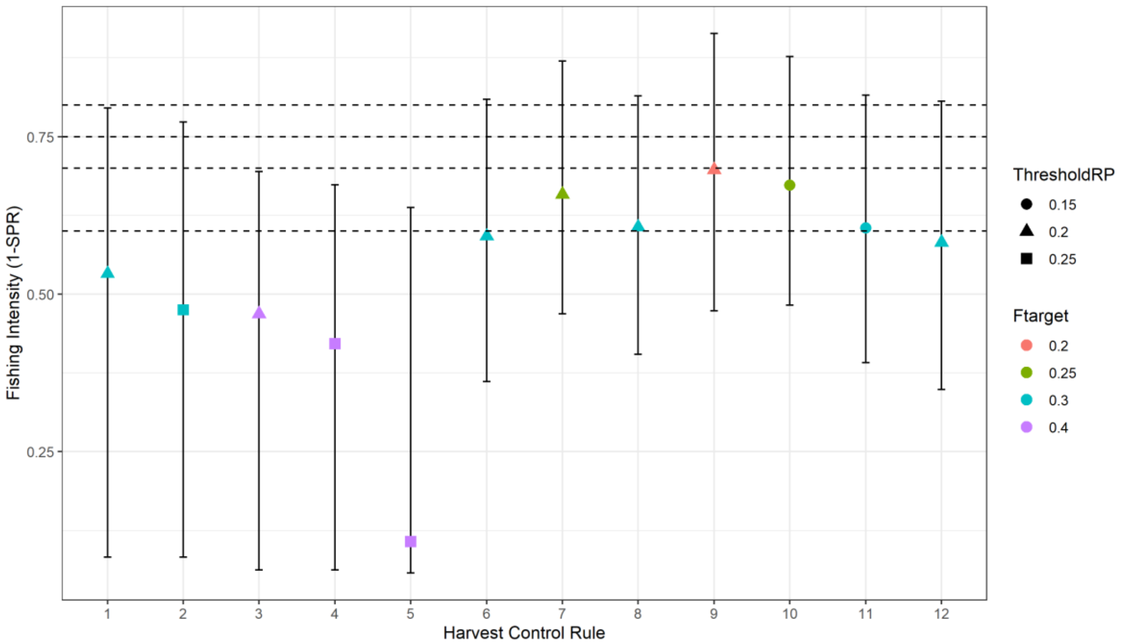

Figure 5. Median (shape) and 5th to 95th quantiles (error bars) of F (1-SPR) for each HCR across 100 iterations, 20 OMs, and the 22-year evaluation period. Colors represent

the F_{target} associated with each HCR, shapes the Threshold reference point associated with each HCR, and the dotted line different F associated with the different F_{target} of $F_{40\%SPR}$, $F_{30\%SPR}$, $F_{25\%SPR}$, $F_{20\%SPR}$.

Figure 6 shows output by HCR for the second status performance metric, the "Probability that SSB is below the equivalent biomass depletion levels associated with the candidates for F_{target}". Note that unlike for the first status performance metric, a lower probability is best, as we want SSB to be high. This was computed for each HCR by counting the number of times across iterations, evaluation years, and OMs that SSB relative to unfished was below the relative SSB associated with each F_{target} relative to the total number of iterations, evaluation years, and OMs. All HCRs have a probability of being lower or equal to their F_{target} that is well above 50% (Fig. 4).

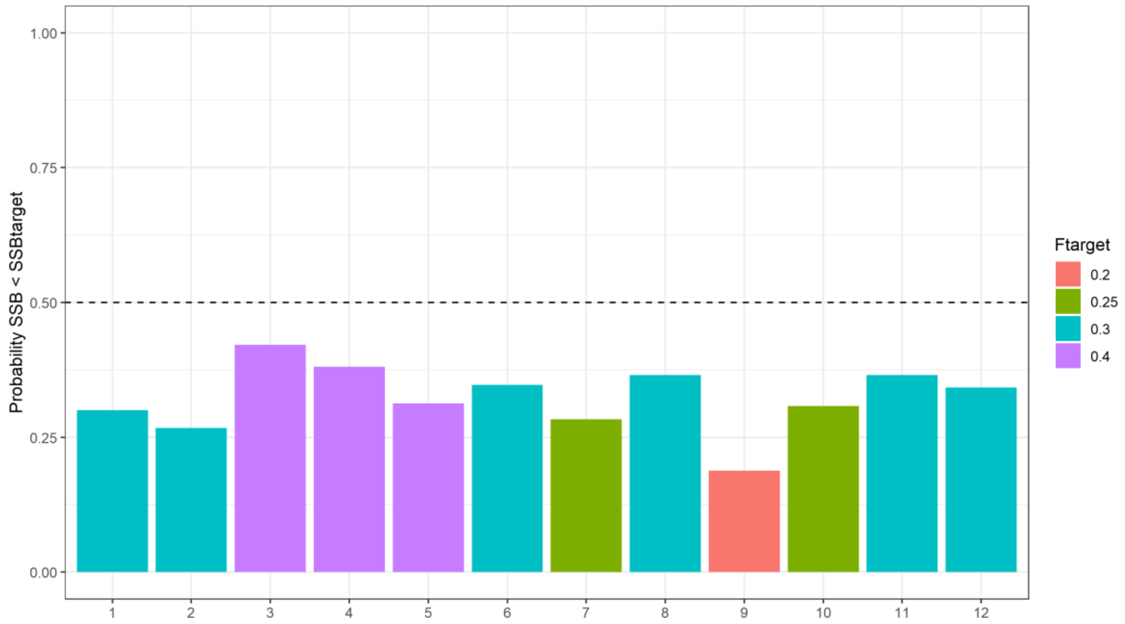

Figure 6. Probability that SSB is below the equivalent biomass depletion levels associated with the candidates for F_{target} for each candidate HCR across 100 iterations, 20 OMs, and the 22-year evaluation period. Bar colors represent the F_{target} associated with each HCR and the dotted line the probability level in the management objective.

Stability Performance Metrics

Figure 7 shows output by HCR for the first stability performance metric, the "Percent change upwards in catches between management periods excluding periods when SSB<LRP". Note that by design the MSE code restrict changes in catch for each fishery (i.e. EPO, WCPO large, WCPO small) to be less or equal to 25% of the TAC in the previous management period unless SSB<LRP, in which case there are no constraints. Indeed, the max % change upwards in catch was 25%, with HCRs 1-5 showing the highest median %upward change (Fig. 7).

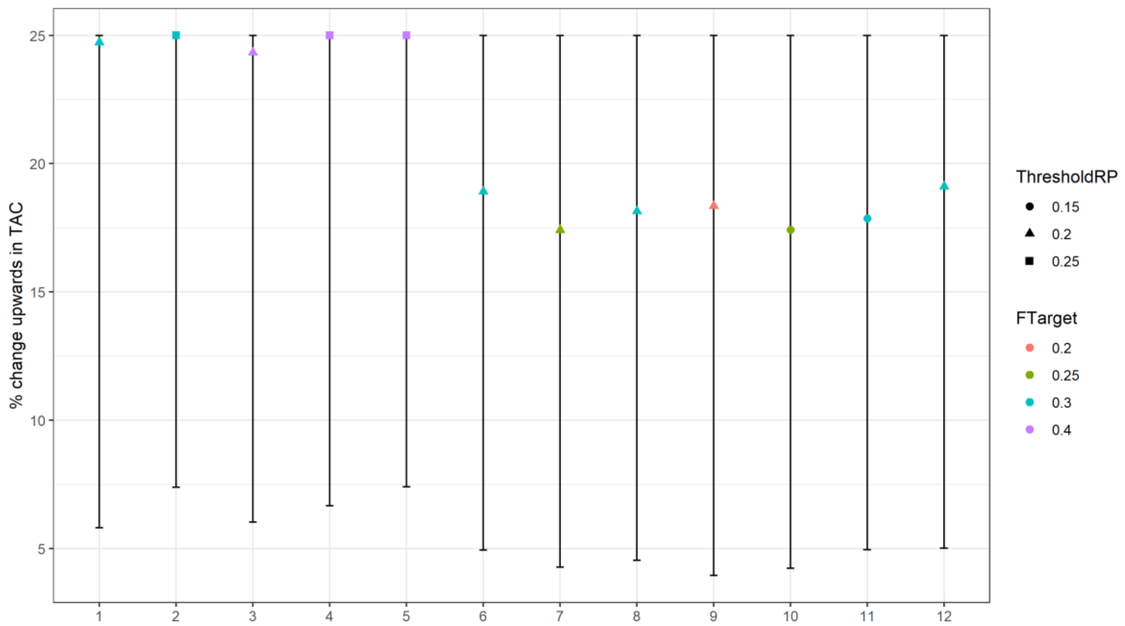

Figure 7. Median (shape) and 5th to 95th quantiles (error bars) of the %change upward in TAC between management periods for each HCR across 100 iterations, 20 OMs, and the 22-year evaluation period. Colors represent the F_{target} associated with each HCR, and shapes the threshold reference point associated with each HCR.

Figure 8 shows output by HCR for the second stability performance metric, the "Percent change downwards in catches between management periods excluding periods when SSB<LRP". As expected, the highest % change downwards in catch was 25% (Fig. 8).

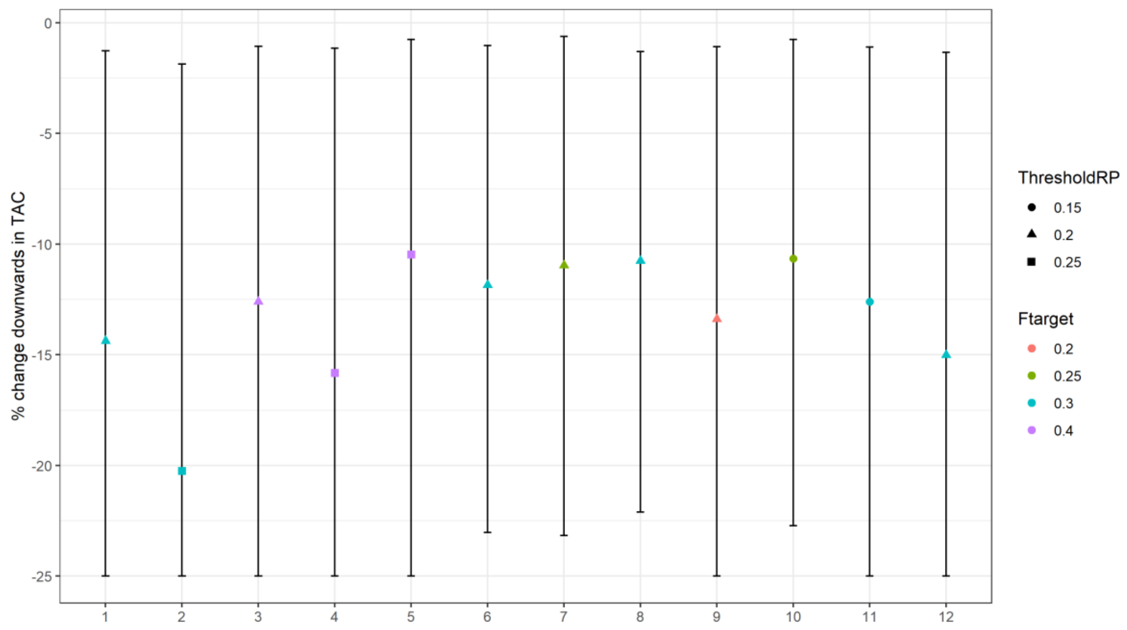

Figure 8. Median (shape) and 5th to 95th quantiles (error bars) of the % change downwards in TAC between management periods for each HCR across 100 iterations, 20 OMs, and the 22-year evaluation period. Colors represent the F_{target} associated with each HCR, and shapes the threshold reference point associated with each HCR.

Yield Performance Metrics

Figure 9 shows output by HCR for the first yield performance metric, the "Median fishery impact (in %) on SSB in the terminal year of the evaluation period by fishery". There were no large differences in impact across HCRs due to the same relative F allocation being used across all HCRs. All HCRs have a median EPO fishery impact across all iterations and OMs between 22 and 24% and a WCPO fishery impact between 76 and 78% (Fig. 9).

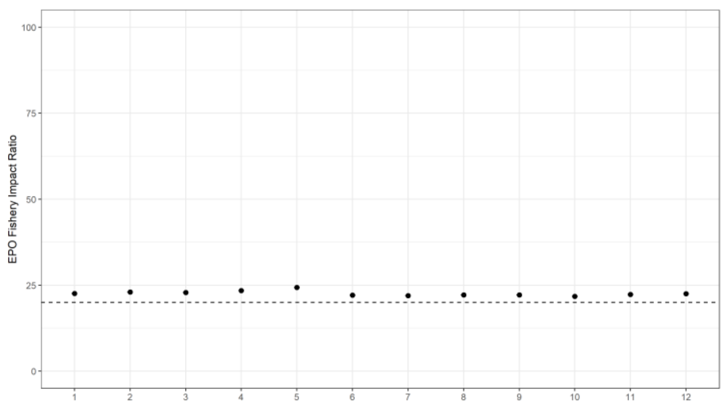

Figure 9. Median EPO % fishery impact in terminal year of the evaluation period for each HCR across 100 iterations, and 20 OMs.

Figures 10 to 13 show the other yield metrics by fishery and across all fisheries. These metrics are the median mean annual yield over years 5-10 of the evaluation period, the median mean annual yield over years 10-22 of the evaluation period, and the median annual yield over the entire evaluation period. For all fisheries, HCRs with the highest F_{target} had the highest catch.

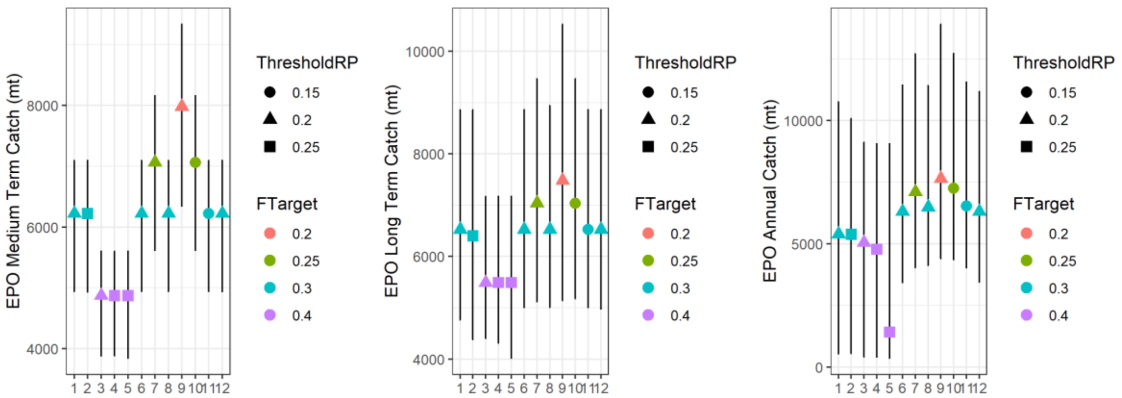

Figure 10. Median (shape) and 5th to 95th quantiles (error bars) of the mean EPO annual yield over years 5-10 (first panel), the mean EPO annual yield over years 10-22 (second panel), and the EPO annual yield (third panel) for each HCR across 100 iterations and 20 OMs. Colors represent the F_{target} associated with each HCR, and shapes the threshold reference point associated with each HCR.

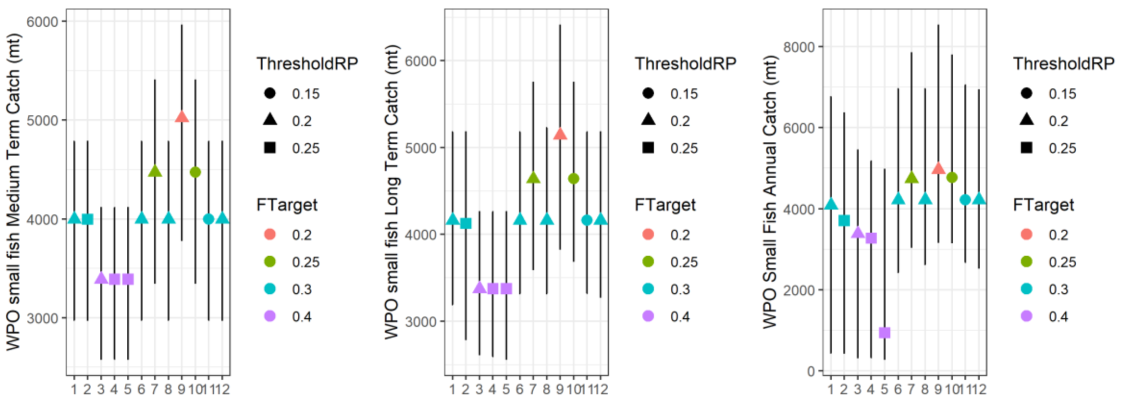

Figure 11. Median (shape) and 5th to 95th quantiles (error bars) of the mean WPO small fish annual yield over years 5-10 (first panel), the mean WPO small fish annual yield

over years 10-22 (second panel), and the WPO small fish annual yield (third panel) for each HCR across 100 iterations and 20 OMs. Colors represent the F_{target} associated with each HCR, and shapes the threshold reference point associated with each HCR.

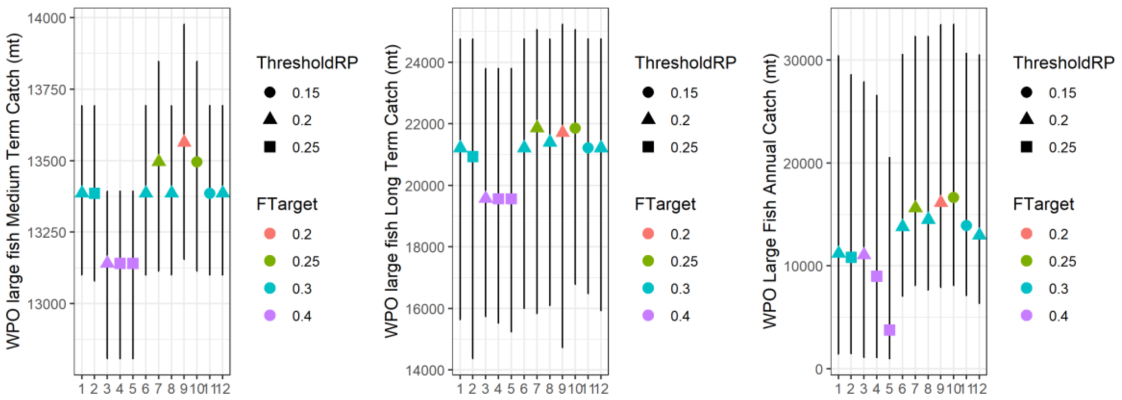

Figure 12. Median (shape) and 5th to 95th quantiles (error bars) of the mean WPO large fish annual yield over years 5-10 (first panel), the mean WPO large fish annual yield over years 10-22 (second panel), and the WPO large fish annual yield (third panel) for each HCR across 100 iterations and 20 OMs. Colors represent the F_{target} associated with each HCR, and shapes the threshold reference point associated with each HCR.

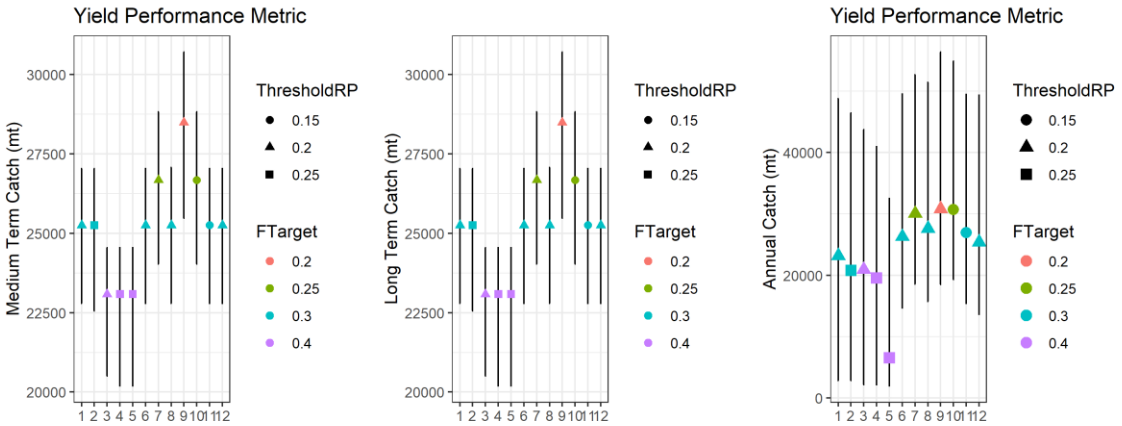

Figure 13. Median (shape) and 5th to 95th quantiles (error bars) of the mean annual yield over years 5-10 (first panel), the mean annual yield over years 10-22 (second panel), and the annual yield (third panel) for each HCR across 100 iterations and 20 OMs. Colors represent the F_{target} associated with each HCR, and shapes the threshold reference point associated with each HCR.

Tradeoffs

As there are tradeoffs between different performance metrics (e.g. safety and yield) no HCR performs best across all performance metrics (Fig. 14).

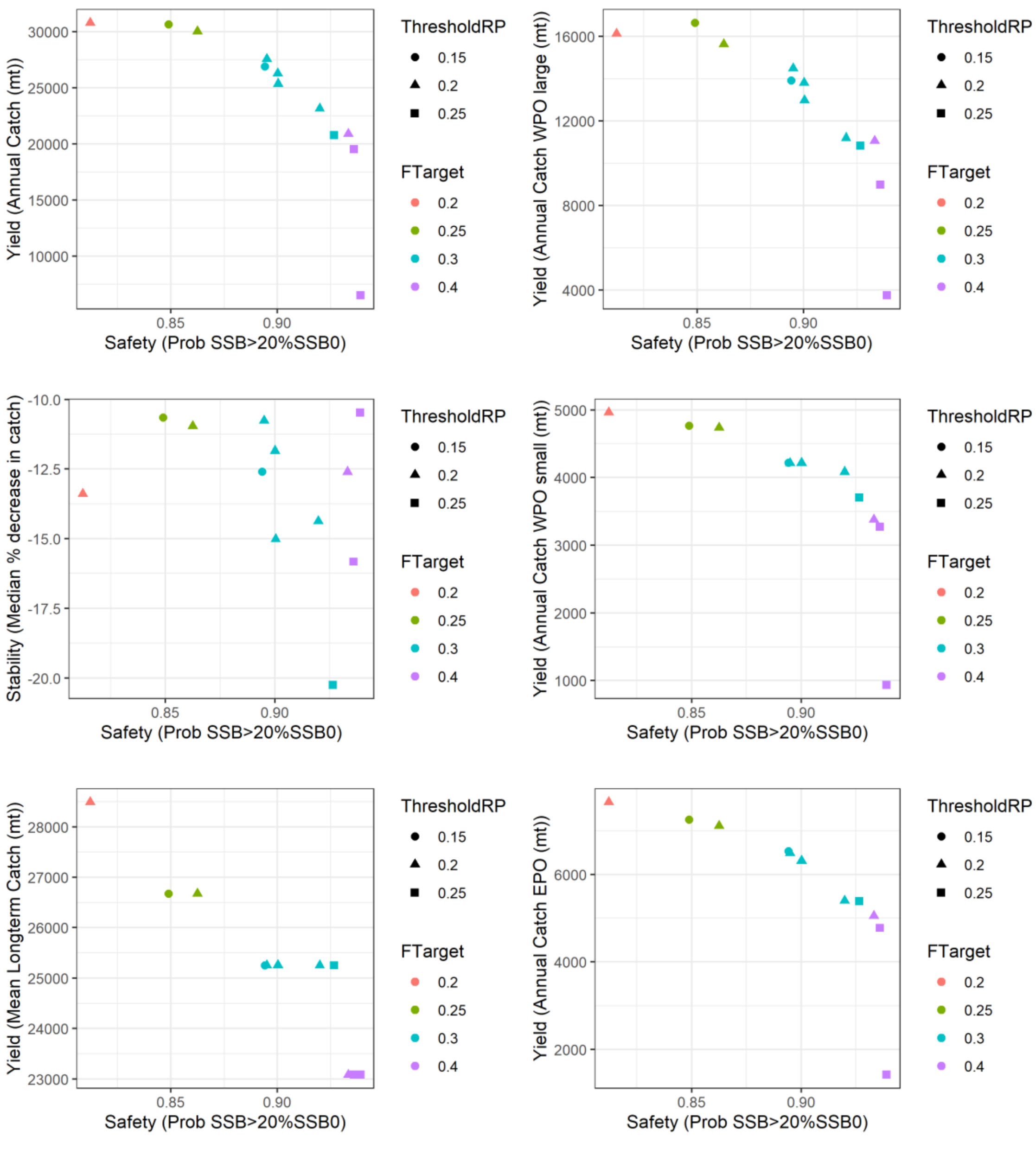

Figure 14. Biplots contrasting different median performance metrics for each HCR across 100 iterations and 20 OMs. Colors represent the F_{target} associated with each HCR, and shapes the threshold reference point associated with each HCR.

We have presented a set of graphics summarizing the performance metrics of interest to the PBF JWG. These could serve as a starting point for the PBF WG to discuss and finalize potential graphics to present at the February JWG meeting.

References

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