Calculation of Fishery Impact Performance Metric for the Pacific Bluefin Tuna Management Strategy Evaluation

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Summary

The Western and Central Pacific Fisheries Commission of the Northern Committee (WCPFC NC) and the Inter American Tropical Tuna Commission (IATTC) requested, via the Joint Working Group (JWG), that the ISC PBF working group develop a Management Strategy Evaluation (MSE) to help inform development of a long-term management strategy for PBF (JWG 2022). As part of the MSE process the JWG proposed a list of operational management objectives and performance metrics with which to evaluate performance of potential management strategies for Pacific Bluefin tuna (JWG22, Annex E). One of the proposed objectives for yield was to "Maintain a proportional fishery impact between the WCPO and EPO similar to the average proportional fishery impact from 1971-1994". Here we detail how this performance metric is calculated for the PBF MSE and present preliminary results of the fishery impact metric for one of the proposed management strategies for PBF.

Introduction

The two Regional Fisheries Management Organizations (RFMOs) tasked with managing the Pacific Bluefin tuna (PBF) stock, namely the Western and Central Pacific Fisheries Commission of the Northern Committee (WCPFC NC) and the Inter American Tropical Tuna Commission (IATTC) requested, via the Joint Working Group (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 proposed a list of operational management objectives and performance metrics with which to evaluate performance of potential management strategies for Pacific Bluefin tuna (JWG22 Annex E). One of the yield objectives was to "Maintain a proportional fishery impact between the Western Central Pacific Ocean (WCPO) and Eastern Pacific Ocean (EPO) similar to the average proportional fishery impact from 1971-1994". Derivation of performance metrics for this objective necessitates calculation of proportional fishery impact by EPO and WCPO and by fishery (Table 1).

Fishery impact examines the effect of a particular fishery group (e.g. by gear or region) on spawning stock biomass (SSB). It is computed by simulating what the SSB would have been in the absence of catches from that fishery group and depends not only on the amount of catch of that fishery group but also on the size composition of that catch. For instance, catching juvenile fish would have a larger impact on SSB than catching the same amount of mature fish as those fish are removed before they reach their full growth potential or reproduce (Wang et al. 2009). Proportional fishery impact is the fishery impact of a particular group relative to the impact of all the fisheries combined and has become a quantity routinely computed and presented to managers in the PBF stock assessment (ISC 2022). Here we detail how a proportional fishery impact metric can be calculated from output of the PBF MSE and present preliminary results of the fishery impact metric for one of the proposed harvest strategies for PBF.

Table 1. List of operational management objectives and performance metrics for Pacific Bluefin tuna for the yield category generated during JWG07 (JWG22, Annex E). SSB refers to female spawning stock biomass, LRP to limit reference point.

Category	Operational Management Objective	Performance Metric
Yield	[Maintain a proportional fishery impact between the WCPO and EPO [similar to the average proportional fishery impact from1971-1994]	Median fishery impact (in %) on SSB in any given year of the evaluation period by fishery and by WCPO fisheries and EPO fisheries The probability that the proportional EPO fishery impact is at least the1971-1994 average in any given year
	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 years5-10 of the evaluation period, by fishery. Expected annual yield over years 10-30 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

We run the PBF MSE with all the potential harvest control rules (HCRs) put forward for harvest strategy '1a' at NC15 (WCPFC 2019, Table 2). To run the MSE we use the framework presented in Tommasi and Lee 2022 and shown in Fig. 1. We run the simulation with no assessment model error (i.e. no estimation model) to reduce run times. The Tommasi and Lee (2022) framework and associated code (available at https://github.com/detommas/PBF_MSE) was modified according to feedback from the November ISC PBF WG meeting to:

- Set a TAC every three rather than two years, following a simulated three-year assessment schedule,
- Run the feedback control MSE simulation for 24 rather than 30 years,
- For all fleets, keep selectivity constant at the 2017-2019 values for the forward simulation. These are the selectivity values also used in the benchmark calculations to compute the F multiplier required to keep fishing intensity at the target level.

We note that the code was also modified to use the Lee et al. 2021 bootstrap correction when generating data from the OM to input into the EM, but this new capability was not used in this analysis as the simulation was run assuming no assessment error.

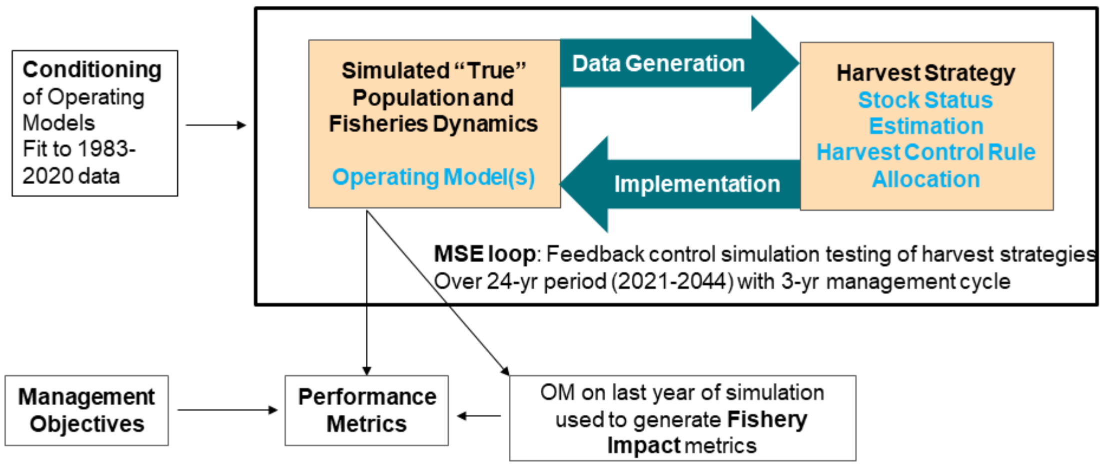

Figure 1. Overview of preliminary PBF MSE framework. Note that for this initial analysis the MSE loop was run assuming no error in data, assessment, or implementation.

Table 2. List of harvest control rules (HCRs) for harvest strategy 1a. The target reference

point (F_{target}) is an indicator of fishing intensity based on SPR. SPR is the spawning stock biomass (SSB) per recruit that would result from the current year's pattern and intensity of fishing mortality relative to the unfished stock. An F_{target} of FSPR40% is associated with a fishing intensity that would leave 40% of the SSB per recruit as compared to the unfished state. An F_{target} of FSPR30% implies a higher fishing intensity (i.e., 1-SPR of 0.7) and would result in a SSB per recruit of 30% of the unfished SPR. The threshold and limit reference points are SSB-based and refer to the specified percentage of unfished SSB ($SSB_{F=0}$). The minimum F refers to the fraction of the F_{target} that the fishing intensity is set to when SSB is below the limit reference point.

HCR	Limit Reference Point	Threshold Reference Point	Target Reference Point	Minimum F
1	5%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR15%	5%F_{target}
2	5%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR20%	5%F_{target}
3	5%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR30%	5%F_{target}
4	5%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR40%	5%F_{target}
5	5%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR20%	5%F_{target}
6	5%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR30%	5%F_{target}
7	5%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR40%	5%F_{target}
8	5%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR30%	5%F_{target}
9	5%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR40%	5%F_{target}
10	7.7%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR15%	5%F_{target}
11	7.7%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR20%	5%F_{target}
12	7.7%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR30%	5%F_{target}
13	7.7%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR40%	5%F_{target}
14	7.7%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR20%	5%F_{target}
15	7.7%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR30%	5%F_{target}
16	7.7%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR40%	5%F_{target}
17	7.7%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR30%	5%F_{target}
18	7.7%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR40%	5%F_{target}
19	15%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR20%	5%F_{target}
20	15%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR30%	5%F_{target}

21	15%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR40%	5%F_{target}
22	15%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR30%	5%F_{target}
23	15%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR40%	5%F_{target}
24	20%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR30%	5%F_{target}
25	20%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR40%	5%F_{target}
26	5%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR15%	10%F_{target}
27	5%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR20%	10%F_{target}
28	5%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR30%	10%F_{target}
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32	5%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR40%	10%F_{target}
33	5%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR30%	10%F_{target}
34	5%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR40%	10%F_{target}
35	7.7%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR15%	10%F_{target}
36	7.7%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR20%	10%F_{target}
37	7.7%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR30%	10%F_{target}
38	7.7%$SSB_{F=0}$	15%$SSB_{F=0}$	FSPR40%	10%F_{target}
39	7.7%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR20%	10%F_{target}
40	7.7%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR30%	10%F_{target}
41	7.7%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR40%	10%F_{target}
42	7.7%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR30%	10%F_{target}
43	7.7%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR40%	10%F_{target}
44	15%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR20%	10%F_{target}
45	15%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR30%	10%F_{target}
46	15%$SSB_{F=0}$	20%$SSB_{F=0}$	FSPR40%	10%F_{target}
47	15%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR30%	10%F_{target}
48	15%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR40%	10%F_{target}
49	20%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR30%	10%F_{target}
50	20%$SSB_{F=0}$	25%$SSB_{F=0}$	FSPR40%	10%F_{target}

As described in Tommasi and Lee (2022), the PBF MSE uses a modified version of the short 2022 Stock Synthesis (SS) PBF stock assessment model (Fukuda et al. 2022) as the base case operating model (OM). The OM has been conditioned using historical data and is run with no estimation using parameters set in the .par file during the forward simulation. Catches in the OM .dat file are updated every three years as set by the TAC determined by the HCR. Thus, in the 24-year simulations a TAC is set eight times. For each of the 50 HCRs, we run 100 different iterations to account for recruitment process uncertainty, for a total of 5,000 24-years runs.

The MSE framework stores all the SS input and output files for the OM for each of the eight management periods. We compute the proportional fishery impact using the algorithm developed by Wang et al. 2009 and customized for PBF in ISC 2013. Specifically, we developed an R script, *impact_calc_h1.R*, that:

- Generates empty folders for each fleet group plus a no fishing scenario and copies into them OM files from the OM folder for the last management time step of the MSE. The OM .dat file includes the 24 years of catches as specified by the HCR in the MSE simulation and these are different for each of the 5,000 runs;
- For each folder, modifies the .dat file to have 0 catches in the specified fleet group (e.g. EPO) or for all fleets in the no fishing scenario;
- Sets the steepness in the .par file to 1;
- The initial F in the model is set by fleet F8. Therefore, if the fleet group for which the impact is calculated includes fleet F8, there is no initial F and the .par file and the .ctl file are modified accordingly;
- Runs the modified OM with no estimation to calculate what the SSB would have been with no catches for the specified fleet group. For the no fishing scenario this is the dynamic SSB0;
- For each fleet group, calculates the difference in SSB between the run with no catches for that fleet group and the original OM run with all the catches;
- Calculates the proportional fishery impact for each fishery group as the ratio of the difference in SSB for that fleet group over the sum of the differences in SSB across fleet groups;
- Calculates the actual impact for each fleet grouping by multiplying the proportional impact above to the impact of all fleets combined calculated as the difference between dynamic SSB0 and the SSB in the original model run.

- Saves the proportional and actual impact for each fleet grouping in a text file for further processing.

The computations above are done for the following fishery groupings: EPO vs. WCPO, EPO vs. WCPO small fish fleet, WCPO large fish fleet, and WCPO mixed fish fleet. Table 3 describes which fleets in the assessment are assigned to each grouping. Additional R scripts that run the algorithm above for multiple iterations and HCRs and generate performance metrics are described in Table 4.

Table 3. List of the fleets present in the base-case operating model of the Pacific Bluefin tuna MSE and the associated gear type, and country and fleet type assigned to for calculation of the proportional fishery impact metric. WCPO is Western Central Pacific Ocean and EPO Eastern Pacific Ocean. WCPO fleets are further separated based on the size of fish caught. WCPO mix fleets catch both large and small fish.

SS Fleet #	Fleet name	Gear Type	Country assigned to for impact calculation	Fleet Type
1	F1JLL	Longline	Japan	WCPO Large
2	F2JSPPS (S1, 3, 4)	Purse Seine	Japan	WCPO Small
3	F3KOLPS	Trawl, Setnet, Troll	Korea	WCPO Mix
4	F4TPSJS	Purse Seine	Japan	WCPO Large
5	F5TPSPO	Purse Seine	Japan	WCPO Large
6	F6JTroll (S2-4)	Troll	Japan	WCPO Small
7	F7JPL	Pole-and-Line, driftnet	Japan	WCPO Small
8	F8JSN(S1-3)	Set Net	Japan	WCPO Small
9	F9JSN(S4)	Set Net	Japan	WCPO Mix
10	F10JSN(HK_AM)	Set Net	Japan	WCPO Mix
11	F11JOthers	Miscellaneous	Japan	WCPO Mix
12	F12TWLLSouth	Longline	Taiwan	WCPO Large
13	F13USCOMM (-2001)	Miscellaneous	United States	EPO
14	F14MEXCOMM (2002-)	Miscellaneous	Mexico	EPO
15	F15EPOSports	Recreational	United States	EPO

16	F16JTroll4Pen	Troll for Penning	Japan	WCPO Small
17	F17TWLLNorth	Longline	Taiwan	WCPO Large
18	F18JSPPS (S2)	Purse Seine	Japan	WCPO Small
19	F19JTroll (S1)	Troll	Japan	WCPO Small
20	F20JSPPS (Penning)	Purse Seine for Penning	Japan	WCPO Small
26	F21Disc_mt	Discard	Korea	WCPO Mix
27	F22Jpn_Disc_Num	Discard	Japan	WCPO Small
28	F23JLL (1993-S1-3)	Longline	Japan	WCPO Large
29	F24EPOsports_early	Recreational	United States	EPO
30	F25EPOsports_Disc	Recreational	United States	EPO

Table 4. Description of R scripts developed to compute the proportional fishery impact metric and associated performance metrics from MSE OM model output. R scripts are available in https://github.com/detommas/PBF_MSE/tree/main/PBF_MSE/Rcode/R_funs for the top two functions or https://github.com/detommas/PBF_MSE/tree/main/PBF_MSE/Rcode for the remaining scripts.

File Name	Description
impact_calc_h1.R	Function to generates a proportional impact time series by EPO vs. WPO and by country from a specified OM
impact_pbfMSE.R	Function that calls function above to calculate impact for the 100 iterations of the specified HCR
PBF_Impact_prll.R	Wrapper that runs the above function in parallel for all the HCRs for the specified harvest strategy
Results_PBF__MSE_impact.R	Processes proportional impact output for each HCR to generate performance metrics and plots

The MSE forward simulation starts from year 2021, after the last year of the 2022 PBF assessment model and MSE conditioning period (Fig. 1). Since proportional fishery impact takes some time to stabilize from the 2020 initial conditions (Fig. 2), we calculate proportional fishing impact for each HCR as the median of the last 10 years of the simulation. We compute the probability of the EPO proportional fishery impact being equal or above the 1971-1994 average, which is 35%, assuming, for each HCR, a normal distribution with a mean equal to the mean EPO proportional fishery impact across the last 10 years of the simulation and 100 iterations and the standard deviation equal to the standard deviation of the mean EPO proportional fishery impact across the last 10 years of the simulation and 100 iterations. Fig. 3 shows that values of EPO proportional fishery impact distribution for HCRs 1 to 9 appear to be normally distributed. The EPO impact for the other HCRs was also normally distributed.

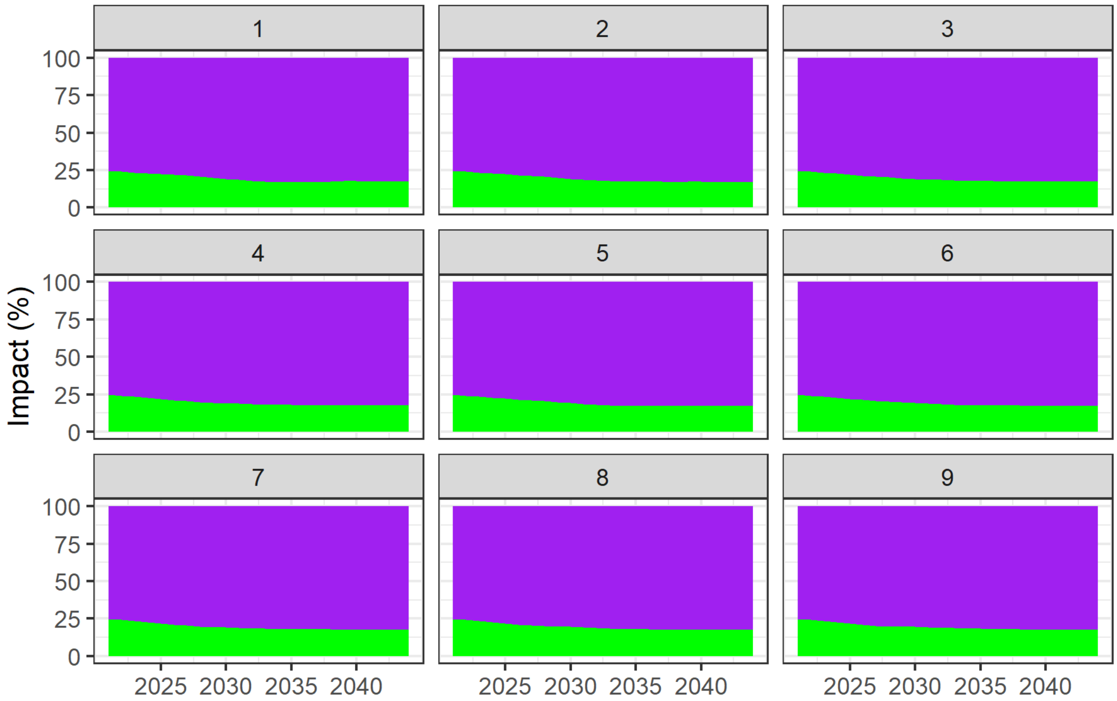

Figure 2. Proportional fishery impact trajectory for the forward MSE simulation period (2021-2044) for the WCPO (purple) and EPO (green) for HCRs 1 to 9.

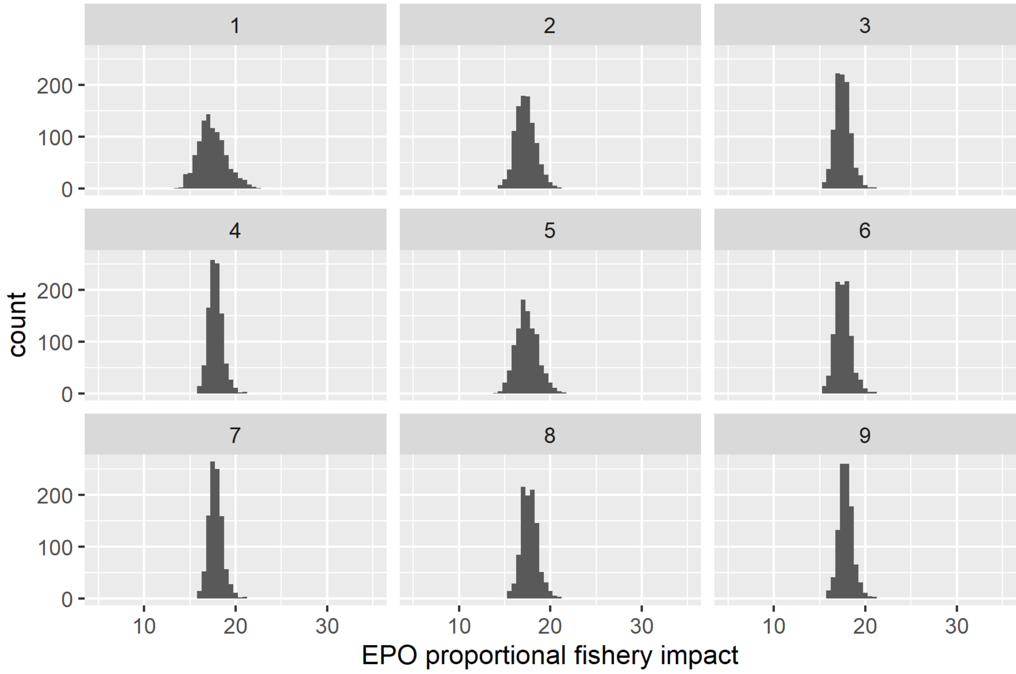

Figure 3. Distribution of EPO proportional fishery impact for across the 100 iterations and last 10 years of the forward MSE simulation period for HCRs 1 to 9.

Results

The median proportional fishery impact for the EPO and WCPO was relatively consistent across HCRs, with all HCRs showing a median EPO impact between 17 and 18% and a WCPO impact between 83 and 82% (Fig. 4).

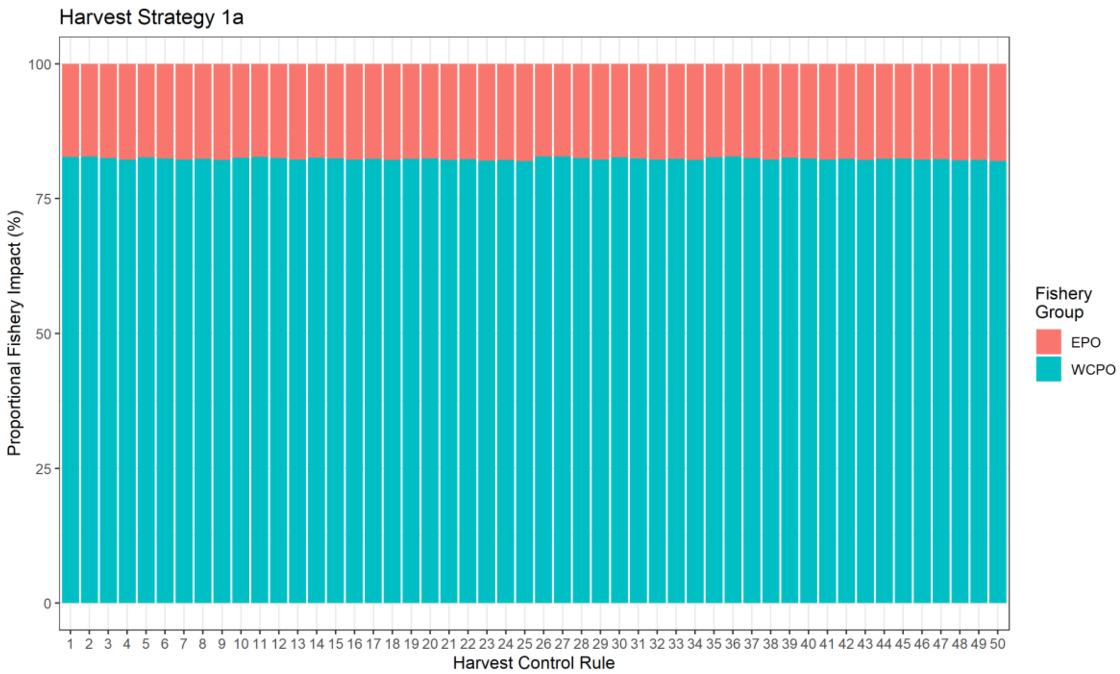

Figure 4. Median proportional fishery impact for the EPO and WCPO for each of the HCRs tested.

The variability around the median EPO proportional fishery impact was also not greatly variable across HCRs, with the 5th quantile ranging from 15 to 17% and the 95th quantiles ranging from 19 to 21% across HCRs (Fig. 5). While variability was small, EPO impact for HCRs with the lowest target reference point (F15) and for some HCRs with a F20 TRP was slightly more variable. Since the median and range of EPO impact was consistently below the 1971-1994 average, all HCRs performed poorly with regards to the following performance metric: “the probability that the proportional EPO fishery impact is at least the1971-1994 average in any given year”. The probability was less than 1% for all the HCRs tested.

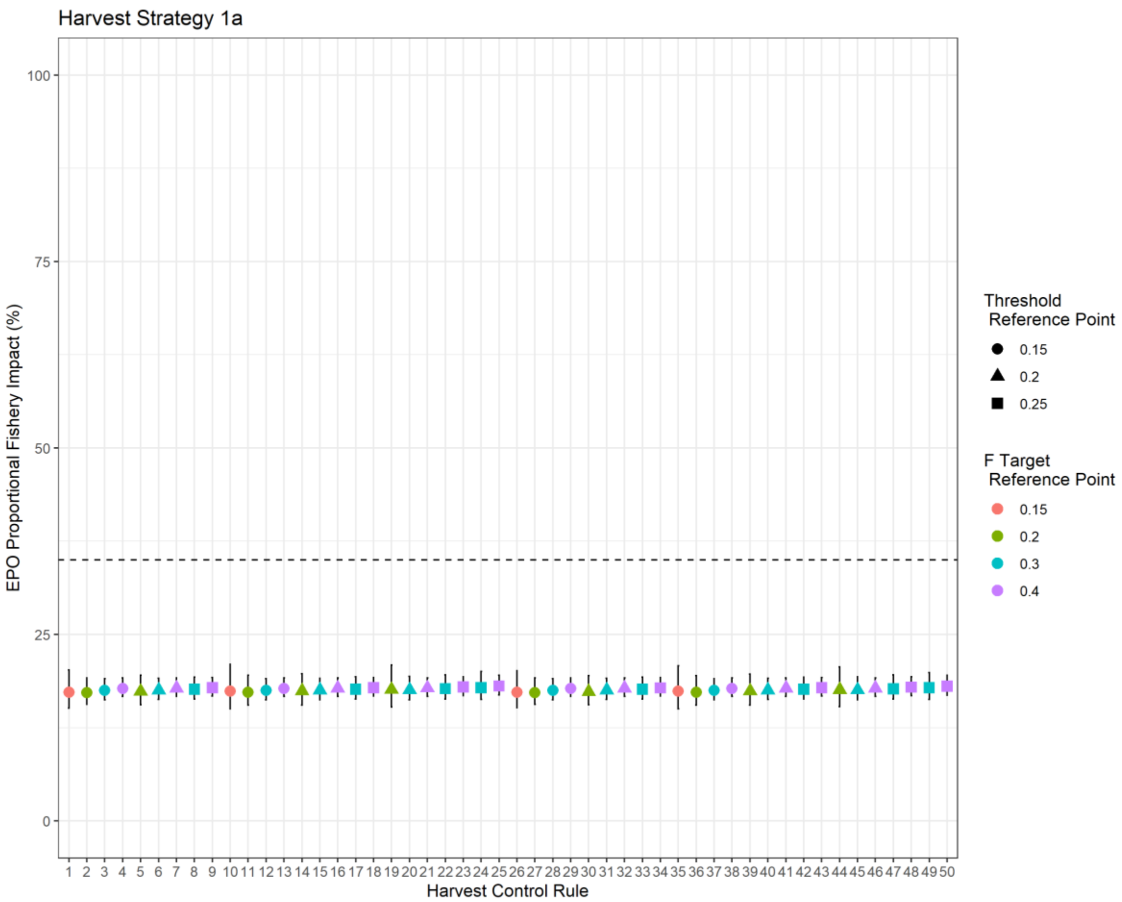

Figure 5. Median and 5th-95th quantile range for the EPO proportional fishery impact for each of the HCRs tested. The dotted line represents the 1971-1994 average EPO proportional fishery impact.

Median impact per country also did not differ substantially between HCRs and ranged from 3 to 4% for the United States, 14 to 15 % for Mexico, 68 to 71% for Japan, 4 to 8% for Chinese Taipei, and 6 to 7% for Korea.

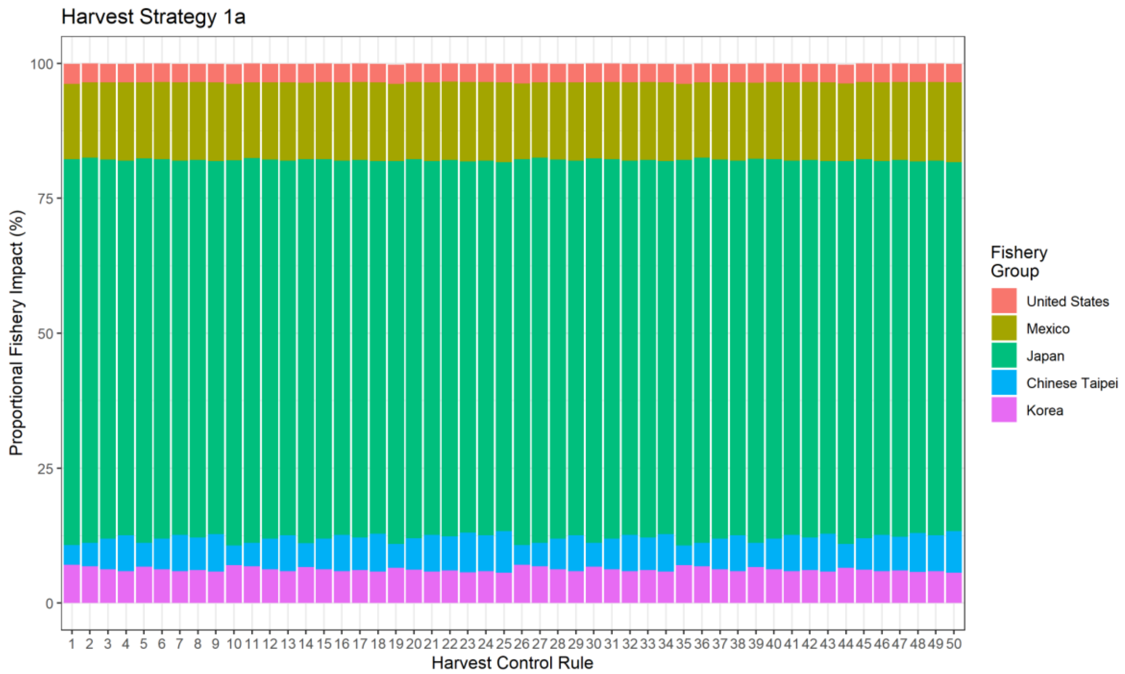

Figure 6. Median proportional fishery impact by country for each of the HCRs tested.

Discussion

The analysis shows a methodology to compute a proportional fishery impact metric. This is done in a post-processing step, once MSE simulations have been completed, and can be applied to the final PBF MSE output to generate the performance metrics requested by the JWG. We also show that no HCR, even with no observation, assessment, or implementation error, is able to meet the first Yield management objective (Table 1) under the currently specified MSE harvest strategy. The median proportional impact across HCRs was 17.6% for the EPO and 82.4% for the WCPO. This is similar to the 17% EPO and 83% WCPO proportional impact estimated for 2020 in the last PBF stock assessment (ISC 2022).

The proportional fishery impact depends on the relative catch of each fleet and their respective selectivity. The HCRs put forward by the JWG control the overall level of fishing intensity via the TRP, but do not provide specifications regarding the allocation of that fishing intensity. In these preliminary runs and Tommasi and Lee (2022) we maintain the recent (2017-2019) exploitation pattern (relative F across fleets, a measure of allocation) and 2017-2019 selectivity in the MSE simulations. Other exploitation pattern given the current selectivity parameters would need to be explored to meet the proposed management objective.

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