Impact of 25% Limit on Quota Change in the Pacific Bluefin Tuna Management Strategy Evaluation on Quantities of Management Interest

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Summary

Here we describe changes made to the Pacific Bluefin tuna (PBF) Management Strategy Evaluation code to implement a constraint on changes in Total Allowable Catch (TAC) between consecutive management periods of no more than 25% as proposed at the 8th Meeting of 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 PBF management. Preliminary results show that a limit on the change in TAC between management periods leads to a slower build-up of fishing intensity up to the target level, an associated slower increase in catch from the initial, low catch levels, an increase in spawning stock biomass (SSB), and an increase in SSB variability.

Introduction

Pacific bluefin tuna (PBF) is a highly migratory species distributed across the subtropical and temperate waters of the North Pacific Ocean (ISC 2022). The major spawning areas are in the western North Pacific Ocean, but a portion of juveniles undertake a trans-Pacific eastward migration to forage in the eastern North Pacific Ocean (EPO) in their first or second year (Fujioka et al. 2018), migrating back to the WPO to spawn.

PBF is a valuable species with a long history of exploitation across the North Pacific Ocean (ISC 2022). Total reported catch of PBF peaked at 47,635 mt in 1956 and declined to the lowest observed catch of 8,853 in mt in 1990 (ISC 2022). According to the latest stock assessment, SSB was highest at 24.3% of unfished levels (24.3%$SSB_{F=0}$) in the early 1960s then declined to 2%$SSB_{F=0}$ in the mid-1980s, increased to 9.7%$SSB_{F=0}$ in the mid-1990s, and then declined to its lowest levels of 1.5%$SSB_{F=0}$ in 2010 (ISC 2022). The biomass decline spurred the two Regional Fisheries Management Organizations (RFMOs) tasked with managing the PBF stock, WCPFC NC and IATTC, to enact management measures to rebuild the stock in 2011, with more stringent catch limits implemented in the mid-2010s (ISC 2022). SSB increased following management actions, reaching 10.2%$SSB_{F=0}$ in 2020 and all stock projections show that the second rebuilding target of 20%$SSB_{F=0}$ will be reached by 2029 with 60% probability (ISC 2022).

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%$SSB_{F=0}$ (JWG 2022). As part of the MSE process, the JWG finalized a list of candidate harvest control rules (HCRs) and reference points to evaluate in the MSE and specified that these HCRs be tested with a limit that constrains changes in TAC between consecutive management periods of no more than 25% (WCPFC 2023a). This was put forward following preliminary analyses of initial candidate HCRs demonstrating that in some years and iterations changes in TAC between management periods may be greater than 25% (Tommasi et al. 2023a). To ensure the HCRs are tuned to meet the stability management objective put forward by the JWG, "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" (WCPFC 2023b), all the latest candidate HCRs put forward by the JWG have a 25% constraint in changes in TAC.

Here we describe how the PBF MSE code was modified to implement the 25% limit on TAC changes and show its effect on quantities of management interest such as catch, fishing intensity, and SSB as compared to a simulation with no TAC limit.

Methods

The preliminary PBF MSE framework (Fig. 1) was outlined in Tommasi and Lee (2022), Tommasi et al. 2023a, Tommasi et al. 2023b, and is available at https://github.com/detommas/PBF_MSE. In this analysis, the MSE is run with no assessment model error (i.e. no estimation model) to reduce run times, and each simulation was run for 24 years and 100 different iterations to account for recruitment process uncertainty. 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. In the full MSE simulation, data from the OM would be sampled with error and fed into the estimation model (EM), i.e. the simulated stock assessment model. However, here we assume there is a perfect estimation with no observation or assessment error. Thus, management quantities, such as reference points and current biomass, are input into the HCRs directly from the OM rather than the EM. 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. However, the catch for the first three years of the simulation is set to the CMM catch limits (see Tommasi and Lee 2022) and thus the HCRs starts being applied over the last 21 years of the simulation.

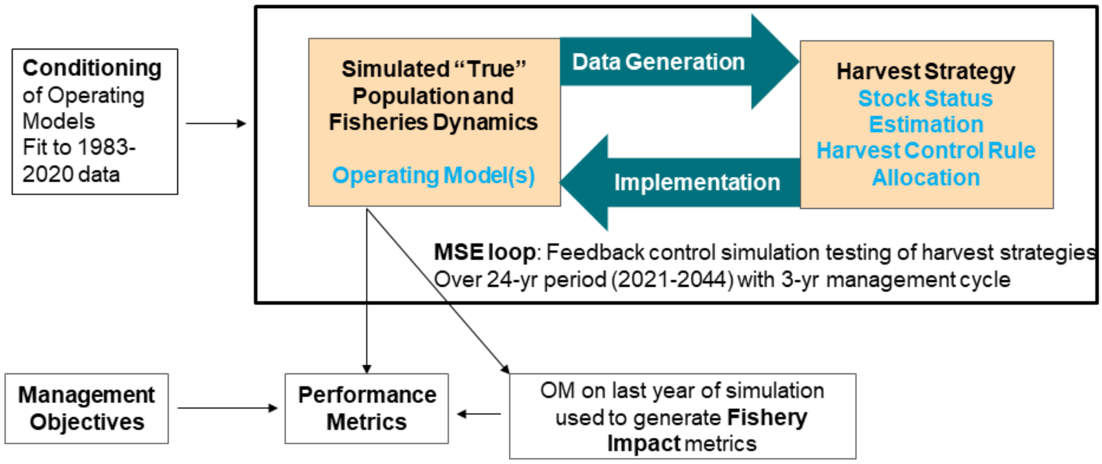

Figure 1. Overview of preliminary PBF MSE framework. Note that for this initial analysis the MSE loop was run assuming no error in data, assessment, or implementation.

We run the same HCRs examined by Tommasi et al. 2023b and refer readers to that working paper for an overview of the HCRs. The only difference between the two analyses is the use of a 25% limit on the change in TAC between management periods in the simulations here presented. Note that following the stability management objective, the limit on the TAC change was only applied when the SSB was above the LRP associated with each HCR. In the PBF MSE framework, management actions are taken every three years, following a simulated stock assessment. The simulated management module finds the TAC that will meet the F_{target} of each HCR given terminal year biomass and recruitment estimates (see Tommasi et al. 2023b for details). F_{target} is an indicator of fishing intensity based on SPR. SPR (spawning potential ratio) is the ratio of the cumulative spawning biomass that an average recruit is expected to produce over its lifetime when the stock is fished at the current fishing level to the cumulative spawning biomass that could be produced by an average recruit over its lifetime if the stock was unfished. For example, an F_{target} of FSPR30% is associated with a fishing intensity that would produce 30% of the spawning potential in an unfished state. In these simulations, once the overall TAC (across fleets and seasons) was computed according to the HCR and current stock status, it was compared to that set three years prior in the previous management period ($TAC_{previous}$). If the new TAC established by the HCR was 25% greater or smaller than the previous, the TAC was set to $1.25*TAC_{previous}$ for an increase or $0.75*TAC_{previous}$ for a decrease. The new TAC was split across fleets and seasons using the same catch ratios as those of the TAC calculated using the HCR and current stock status. The modified HCR functions are *PBF_MSE_hs1_25for.R* and *HCR1a_pbf_byfleet_f_25for.R* for HCRs 1 to 7, 11, and 12, *PBF_MSE_hs1_hcr8_25for.R* and *HCR8_pbf_byfleet_f_25for.R* for HCR8, and *PBF_MSE_hs2_910_25for.R* and *HCR2_pbf_byfleet_f_25for.R* for HCRs 9 and 10. All are available at https://github.com/detommas/PBF_MSE/tree/main/PBF_MSE/Rcode/R_funs. The output of the simulation for each HCR was plotted in R version 4.1.3 to assess trends in relative SSB, fishing intensity, and catch. The code read_output_pbfMSE.R available at https://github.com/detommas/PBF_MSE/blob/main/PBF_MSE/Rcode/read_outpt_pbfMSE.R was used once the MSE simulations were completed to collate the output.txt file produced by each iteration into one large text file containing, for each HCR, output from all the iterations. These output files for each HCR were then read by the *HCR_check_plots25.R* code available at https://github.com/detommas/PBF_MSE/tree/main/PBF_MSE/Rcode to generate the plots shown here.

Results

Without the limit on the change in TAC between assessment periods, there is a rapid increase in median catch from starting levels set by the CMM up to a stationary level associated with the median biomass set by the F_{target} rate (Fig. 1 and Fig. 2). The rate of increase is HCR-specific, depending on its F_{target}, control points and associated rate of change in fishing intensity when SSB is below the threshold reference point. HCR5 actually has initial large drop in catch as SSB was below its limit reference point (LRP) of 20%$SSB_{F=0}$, the highest among the HCRs. Nevertheless, after the initial reduction, there is an aggressive increase in catch even for HCR5 (Fig. 1) as SSB quickly increases above the LRP after the initial reduction in catch (Fig. 2). Once target levels are reached, median catch remains constant, but there is high variability between iterations (Fig. 1). By contrast, when the 25% limit is imposed the initial TAC increase is less aggressive (Fig. 3) than what would have been associated with each HCR (Fig. 1) and median fishing intensity only reaches the F_{target} at the end of the simulation (Fig. 4). This leads to median SSB increasing more rapidly and overshooting levels associated with the F_{target} (Fig. 5). For most HCRs, median SSB reaches levels close to those associated with the F_{target} at the end of the simulation (Fig. 5). However, for HCR4, HCR5, and HCR9 median SSB remained above target levels at the end of the simulation (Fig. 5). The increase in SSB is particularly large for HCR5, since catch can only increase very slowly from the low levels set by the first large decrease in catch when SSB was below the LRP (Fig. 5 and Fig. 1).

By contrast, with no limit on TAC increases, median fishing intensity reaches F_{target} levels quickly (Fig. 6) and median SSB stabilizes to target levels faster and is less variable (Fig. 2).

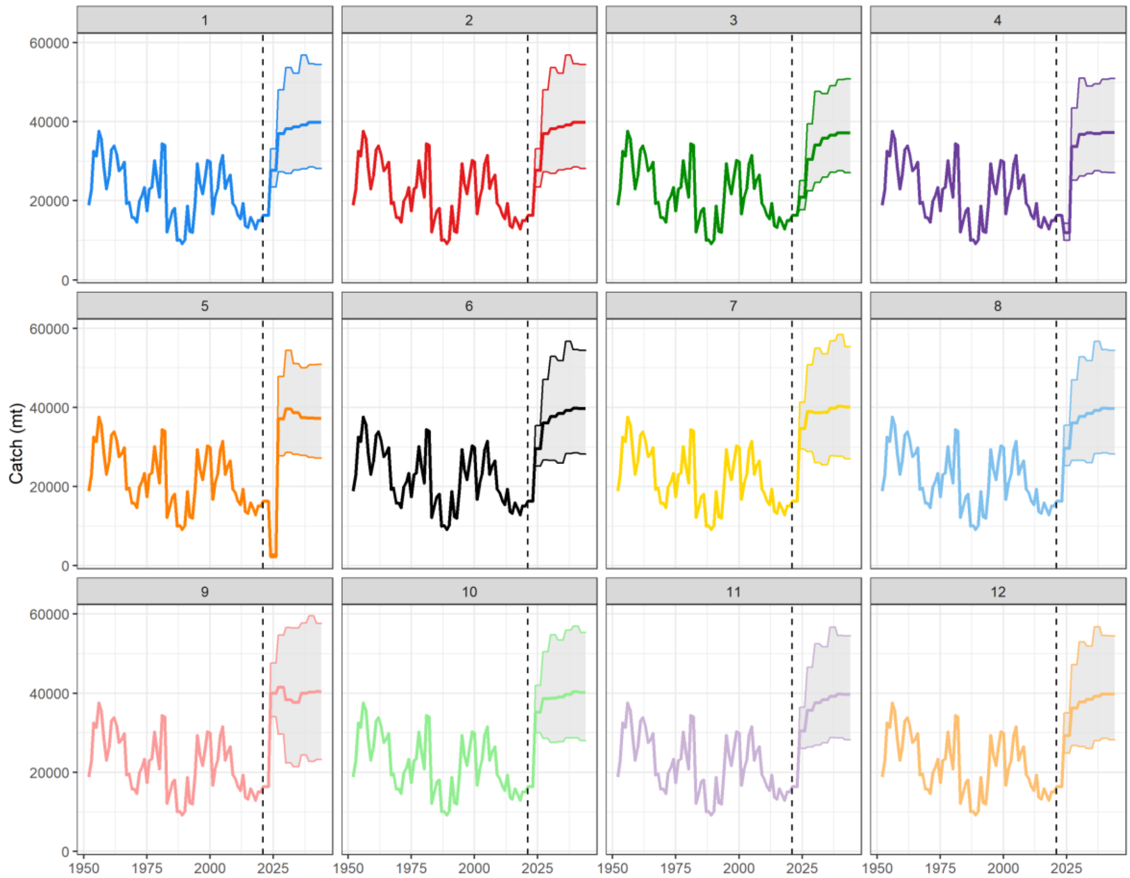

Figure 1. Historical trends in catch from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median catch (thick color line) across all iterations for each harvest control rule (HCR) from the PBF MSE with no limit on the change in TAC between management periods. The vertical dotted line marks the end of the historical estimates and start of the MSE simulation output. For the MSE output, the grey shading represents trends in the 5th to 95th quantiles of catch.

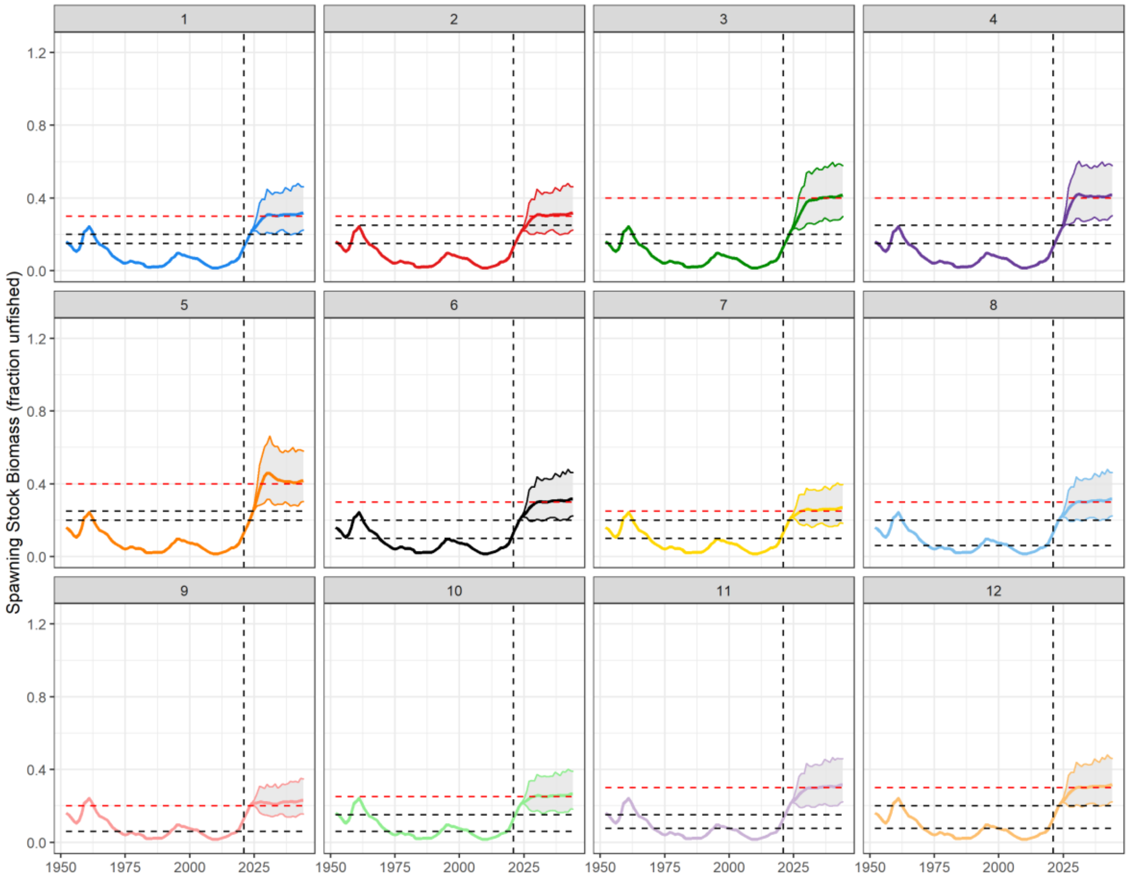

Figure 2. Historical trends in spawning stock biomass (SSB) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median SSB (thick color lines) across all iterations for each harvest control rule (HCR) from the PBF MSE with no limit on the change in TAC between management periods. The vertical dotted line marks the end of the historical estimates and start of the MSE simulation output. For the MSE output, the grey shading represents trends in the 5th to 95th quantiles of SSB. The threshold and limit reference points associated with each HCR are shown as black horizontal dotted lines, while SSB levels associated with the F_{target} are highlighted as red dotted lines.

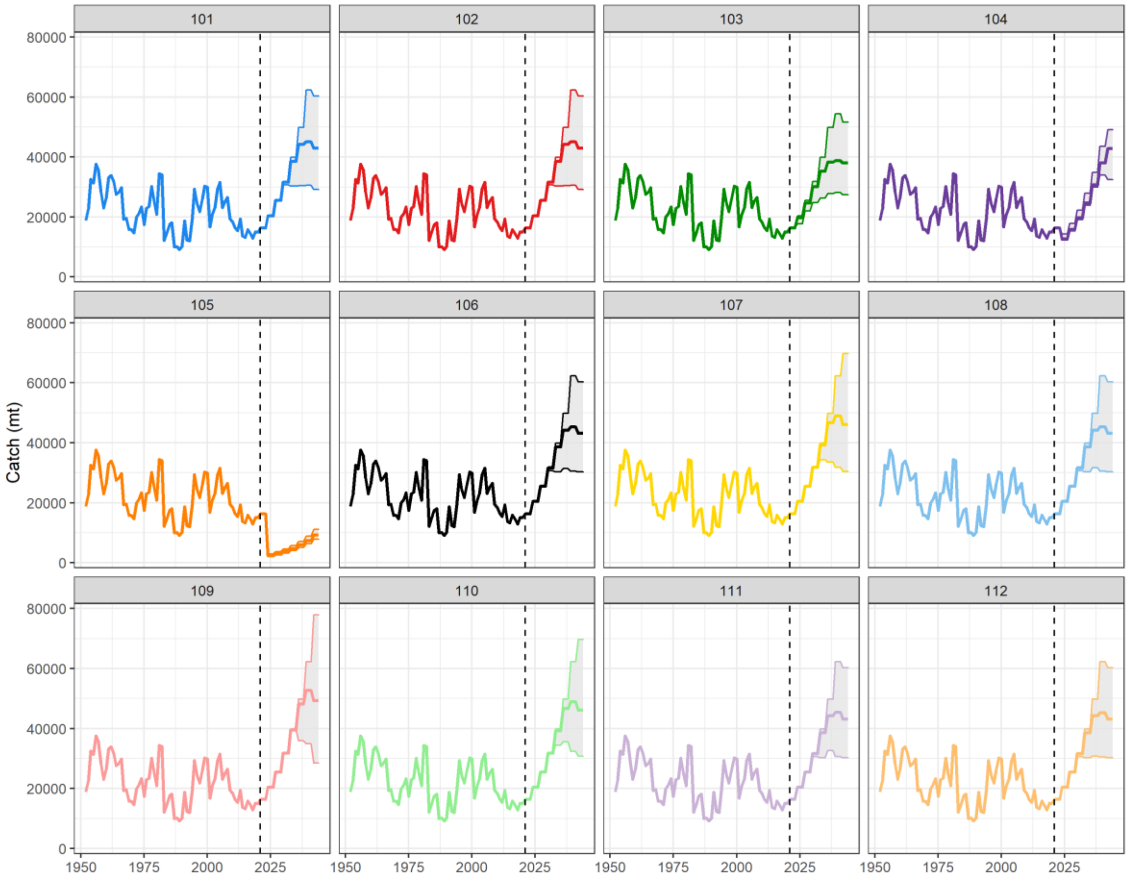

Figure 3. Historical trends in catch from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median catch (thick color line) across all iterations for each harvest control rule (HCR) from the PBF MSE with a 25% limit on the change in TAC between management periods when SSB ≥ LRP. The vertical dotted line marks the end of the historical estimates and start of the MSE simulation output. For the MSE output, the grey shading represents trends in the 5th to 95th quantiles of catch. Note that HCRs are labelled 101 to 112 to differentiate them from the ones in Figure 1, but the only difference between HCRs is the implementation of the limit to the change in TAC.

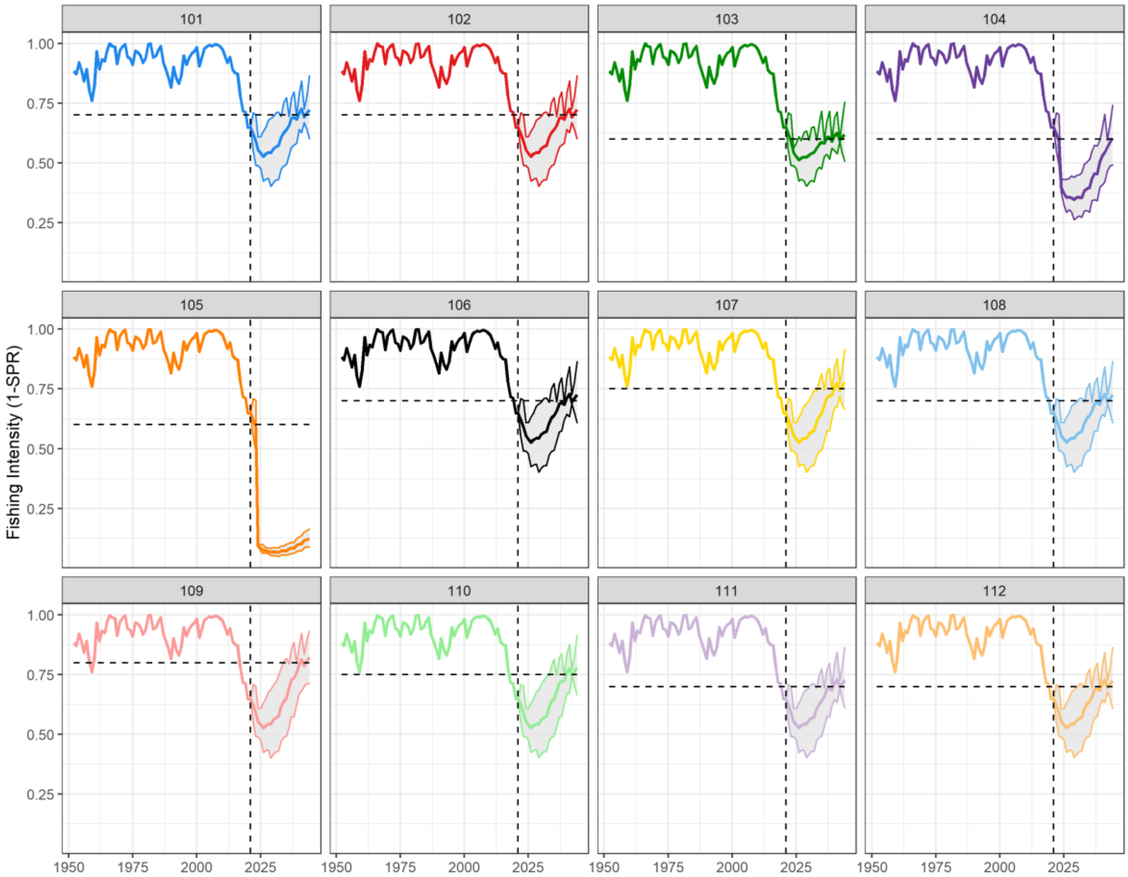

Figure 4. Historical trends in fishing intensity (F, 1-SPR) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median F (thick color line) across all iterations for each harvest control rule (HCR) from the PBF MSE with a 25% limit on the change in TAC between management periods when SSB ≥ LRP. The vertical dotted line marks the end of the historical estimates and start of the MSE simulation output. For the MSE output, the grey shading represents trends in the 5th to 95th quantiles of F. The target reference point associated with each HCR is shown as a horizontal dotted line. Note that HCRs are labelled 101 to 112 to differentiate them from the ones in Figure 1, but the only difference between HCRs is the implementation of the limit to the change in TAC.

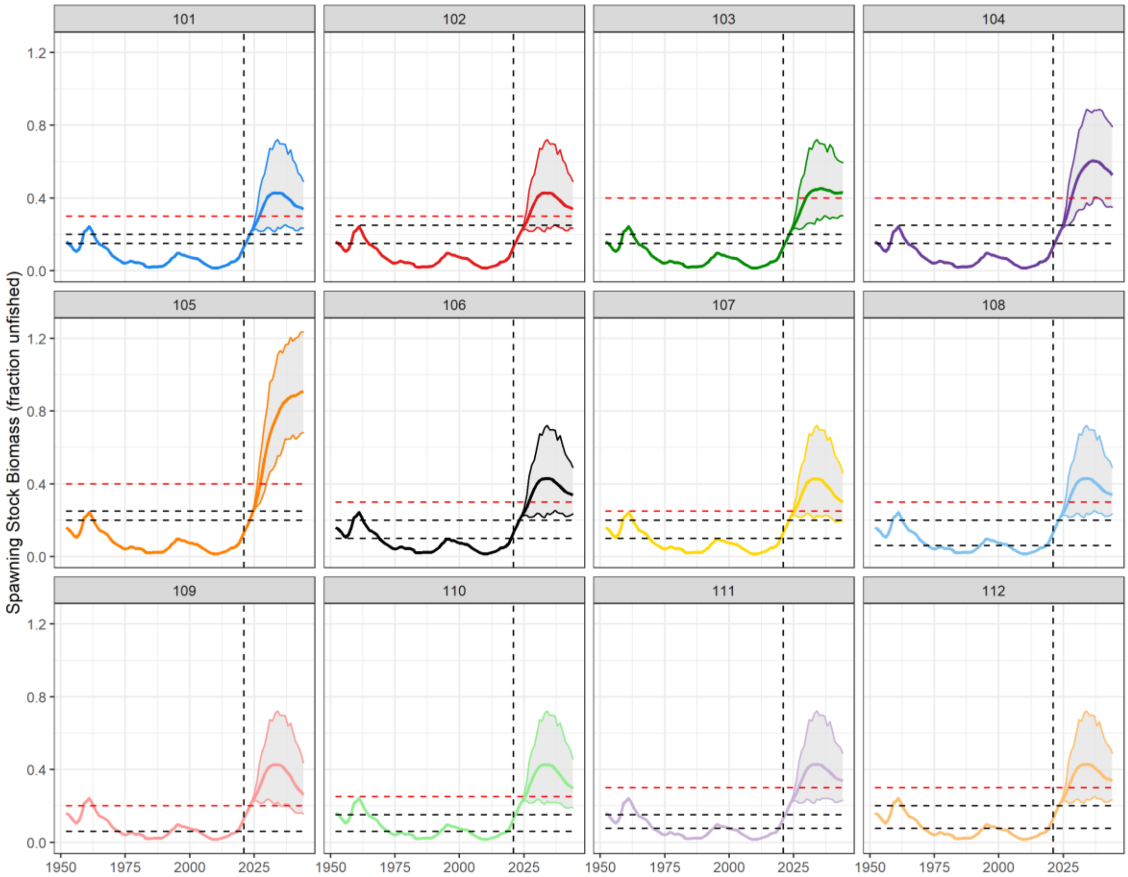

Figure 5. Historical trends in spawning stock biomass (SSB) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median SSB (thick color lines) across all iterations for each harvest control rule (HCR) from the PBF MSE with a 25% limit on the change in TAC between management periods when SSB ≥ LRP. The vertical dotted line marks the end of the historical estimates and start of the MSE simulation output. For the MSE output, the grey shading represents trends in the 5th to 95th quantiles of SSB. The threshold and limit reference points associated with each HCR are shown as horizontal dotted lines, while SSB levels associated with the F_{target} are highlighted as red dotted lines. Note that HCRs are labelled 101 to 112 to differentiate them from the ones in Figure 1, but the only difference between HCRs is the implementation of the limit to the change in TAC.

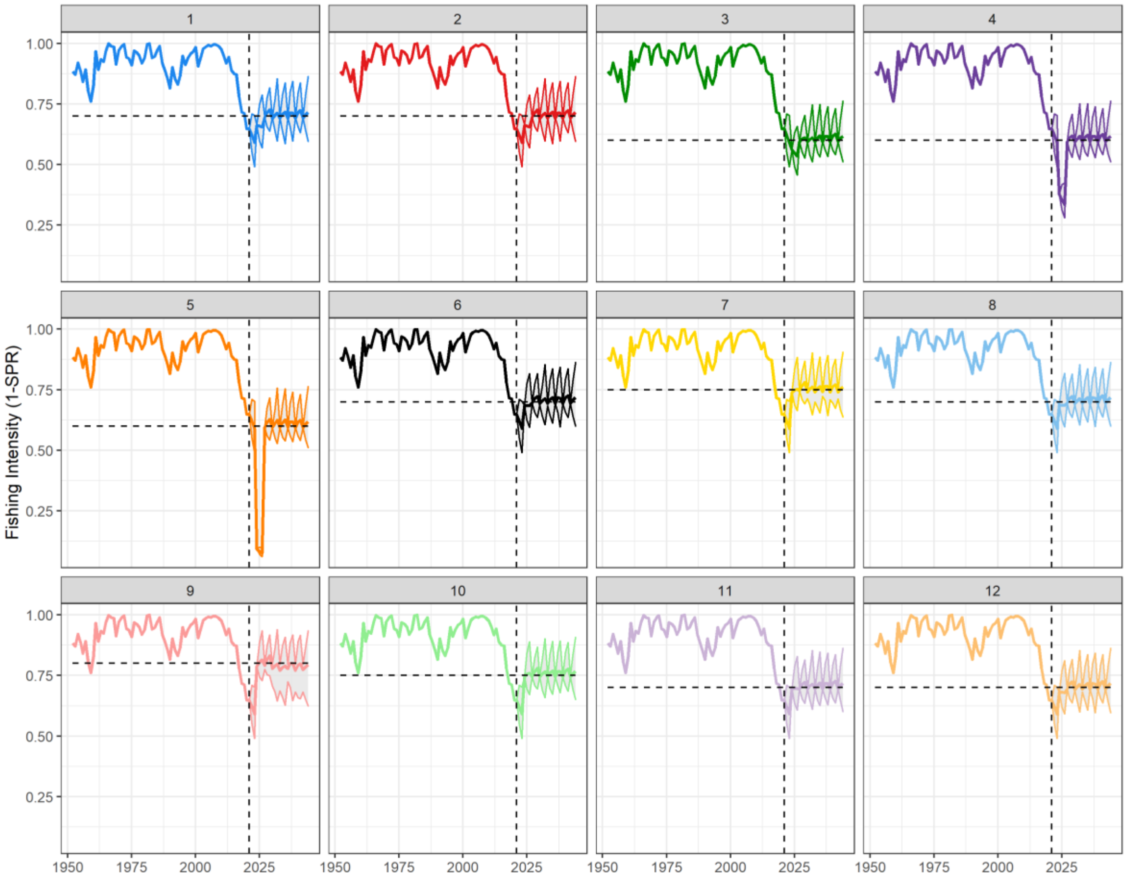

Figure 6. Historical trends in fishing intensity (F, 1-SPR) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median F (thick color line) across all iterations for each harvest control rule (HCR) from the PBF MSE when there was no limit on the TAC change between management periods. The vertical dotted line marks the end of the historical estimates and start of the MSE simulation output. For the MSE output, the grey shading represents trends in the 5th to 95th quantiles of F. The target reference point associated with each HCR is shown as a horizontal dotted line.

The addition of a TAC limit to the management module in the PBF MSE framework works as expected, with the percent change downwards or upwards in catches between management periods, excluding periods when SSB is below the limit reference point (LRP), being bound to 25% (Table 1). Note that, once the 25% limit was imposed, there was no downward change in TAC for HCR5 when SSB ≥ LRP, as the only downward change occurs initially (Fig. 3) when SSB was below the LRP (Fig. 5). Furthermore, for all HCRs, there isn’t much variability in catch during rebuilding as increases are limited to 25% (Fig. 3). Thus, the median % change upward across all iterations and simulation years is the same as the maximum (Table1).

Table 1. Minimum and median % change downwards in catches between management periods and maximum and median change upwards in catches across all 100 iterations and simulation years for each HCR when there is a 25% limit on TAC changes between management periods. The limit only applies when spawning stock biomass (SSB) ≥ limit reference point (LRP).

HCR	% Change downwards in catches between management periods when SSB ≥ LRP		% Change upwards in catches between management periods when SSB ≥ LRP	
	Minimum	Median	Maximum	Median
1	25	9	25	25
2	25	9	25	25
3	25	8	25	25
4	25	25	25	25
5	NA	NA	25	25
6	25	9	25	25
7	25	12	25	25
8	25	9	25	25
9	25	16	25	25
10	25	12	25	25
11	25	9	25	25
12	25	9	25	25

Discussion

We detail and provide links to the R code implementing in the PBF MSE framework the 25% limit on TAC changes between management periods as proposed by the JWG. The code was tested in a simulation and works as expected to limit changes in TAC when SSB ≥ LRP to 25%. The associated changes in quantities of management interest are presented allowing evaluation of the impact of the TAC change limit on management objectives.

PBF catches are currently low following strict management measures to ensure rebuilding. Thus, limiting TAC changes to 25% of levels in the previous management period results in a more gradual increase in catch from these current low levels, leading to a much slower build up to target fishing intensity as compared to simulations with no limit on TAC changes. The lower fishing intensity for much of the simulation period leads to higher and more variable biomass than when no limit on TAC change is implemented, with SSB increasing above target levels for every HCR. The response of SSB to the limit on TAC change was most drastic for HCR5 and least for HCR3. HCR5 imposed an additional catch reduction at the beginning of the simulation due to SSB being below its LRP. The gradual 25% increase from these even lower catch levels led to fishing intensity never reaching target levels at the end of the simulation time frame and to a drastic increase in SSB. Rather than starting in 2021 as the current simulation, the final base case MSE will start at conditions estimated by the upcoming assessment in March 2024. It is expected biomass will be higher than the LRP associated with HCR5. This would prevent the large drop in catch and slow increase to target levels observed here.

Nevertheless, for all HCRs, the addition of the limit on TAC changes resulted in a longer phase of the simulation with dependence on initial conditions. HCRs only reached the stationary phase, with median SSB and fishing intensity at target levels, at the end of the simulation. Thus, an evaluation period longer than 20 years would be required to better assess the behavior of each HCR in the long-term. Once the final base case operating model (OM) has been determined based on the upcoming PBF stock assessment, we suggest carrying out a similar simulation under perfect information but with a longer evaluation period to better assess the MSE simulation time frame required when the 25% limit on TAC change is implemented using the final base case OM. It may also be important to carry out a robustness test with a multi-year drop in recruitment to assess the impact of the limit on TAC change when biomass is decreasing and the reduction in TAC may be less than that prescribed by the HCR with no limit on TAC change.

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