Implementation of 2-year lag between stock status estimation and management action in the Pacific Bluefin tuna management strategy evaluation

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February 2024

Working document submitted to the ISC Pacific bluefin tuna Working Group, International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), from 29 February to 8 March 2024, Kaohsiung Taiwan.

Summary

Previous runs of the Pacific Bluefin tuna (PBF) management strategy evaluation (MSE) set a total allowable catch (TAC) based on the previous year assessment output. In reality, however, due to constraints with data availability, there is a 2-year lag between the end year of the PBF assessment and when its output is used to inform a management action. We therefore modified the PBF MSE code to implement a 2-year lag between assessment and TAC application and show how this change affects fishing intensity (F), spawning stock biomass (SSB), and catch for simulations with and without a 25% limit on TAC changes between assessment periods.

Introduction

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) on PBF management, 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 this MSE process, the ISC PBF WG group is developing the PBF MSE framework and associated code. Preliminary runs with perfect data, estimation, and implementation, have been run to ensure the operating model and management strategies have been coded correctly (Tommasi et al. 2023a), help finalize a set of HCRs to test in the final MSE (Tommasi et al. 2023b) or assess the impact of the 25% limit on changes in TAC between consecutive management periods (Tommasi and Lee 2023). In these runs the TAC derived from output from the estimation model (i.e. the simulated stock assessment) was applied the year following the end year of the estimation model.

At the last PBF WG meeting it was pointed out that there is actually a 2-year lag between the end year of the assessment and the management action it informs (ISC 2023). For instance, the PBF stock assessment completed and presented to managers in 2022 ended in fishing year 2020 (July 2020-June 2021). The PBF WG therefore recommended that the PBF MSE be modified to reflect this lag (ISC 2023). Here, we demonstrate how this 2-year lag was implemented in the PBF MSE code and assess HCR performance with the lag, with and without the 25% TAC limit.

Methods

The preliminary PBF MSE framework 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. estimation model same as operating model) to reduce run times, and each simulation was run 100 different iterations to account for recruitment process uncertainty. There is also no implementation error. 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. Input to inform the HCR is taken directly from an EM that has fixed parameters same as the OM, and sees perfect data. The TAC set by the HCR is then applied to the following three years. Thus, the OM .dat files are updated every three years as set by the TAC determined by the HCR and in each 24-year long simulation a TAC is set 8 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.

Previous MSE runs implemented the TAC the year following the end of the assessment model and thus the EM (or the perfect EM same as OM) had the same end year as the OM (Fig. 1, top panel). In this updated code, rather than the EM seeing the data up to end of the OM, there is a 1-year lag between the end of the OM and the data fed into the EM (Fig. 1, bottom panel). However, the TAC is still applied over the same time frame, leading to a 2-year lag between the end of the EM and when the TAC is applied (Fig. 1, bottom panel). The PBF MSE function *PBF_MSE_hs1_for.R* has been modified to now include a lag parameter specifying the lag between the end of the EM and the calculation of the TAC. In this case the lag is specified as being 1 year, which then leads to a 2-year lag between the end of the EM and when the TAC is applied.

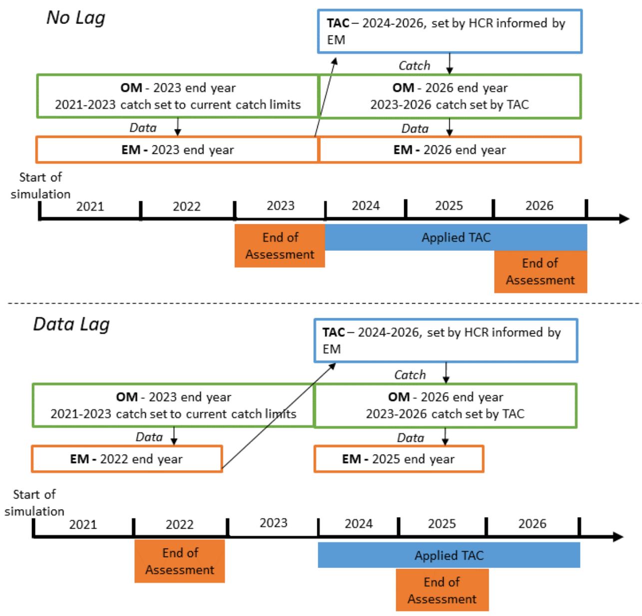

Figure 1. Overview of preliminary PBF MSE framework workflow with and without lags in data availability between the operating model (OM) and estimation model (EM). Note the difference in the timing of the end of the assessment (orange box) relative to the application of the TAC (blue box) between the two panels.

We run all the 12 final HCRs put forward by the JWG with the 25% limit on the change in TAC between management periods (WCPFC 2023a) as examined by Tommasi and Lee 2023 and refer readers to that working paper for an overview of the HCRs and how they are implemented in the MSE framework. Note that following the stability management objective specified by the JWG (WCPFC 2023b), the limit on the TAC change was only applied when the SSB was above the LRP associated with each HCR. We also first run a simulation with no limit on TAC change between management periods to assess the impact of the lag separate from that of the limit on TAC change relative to a no lag simulation. Given the delay in reaching target fishing intensities when the TAC limit is implemented that simulation is run for 48 rather than 24 years.

Results

The implementation of a 2-year lag between the end of the estimation model and when management is applied results in a steeper initial drop in fishing intensity (F) as compared to a No Lag simulation as the biomass is more depleted in 2022 as compared to 2023 (compare Fig. 2 and 3). The reduction in F is particularly evident for HCRs 1 to 5, which have the highest LRPs of 15%$SSB_{F=0}$ (HCRs 1 to 4) or 20%$SSB_{F=0}$ (HCR 5) (Fig. 3). SSB in 2022 was estimated to be below these control points, requiring a drastic reduction in F. However, in 2023, SSB was only below the 20%$SSB_{F=0}$ LRP of HCR 5 and thus all other HCRs saw a more moderate reduction in F than when a lag was present (Fig. 2). Note also that when no data lag is present there is a see-saw pattern in median F as, with no data or assessment error, median F always goes to the F_{target} the year following the assessment and then drifts away from the F_{target} the following two years according to random variability in recruitment until the next assessment (Fig. 2). However, with a data lag there is variability around the F_{target} even during the first year the TAC is implemented (Fig. 3).

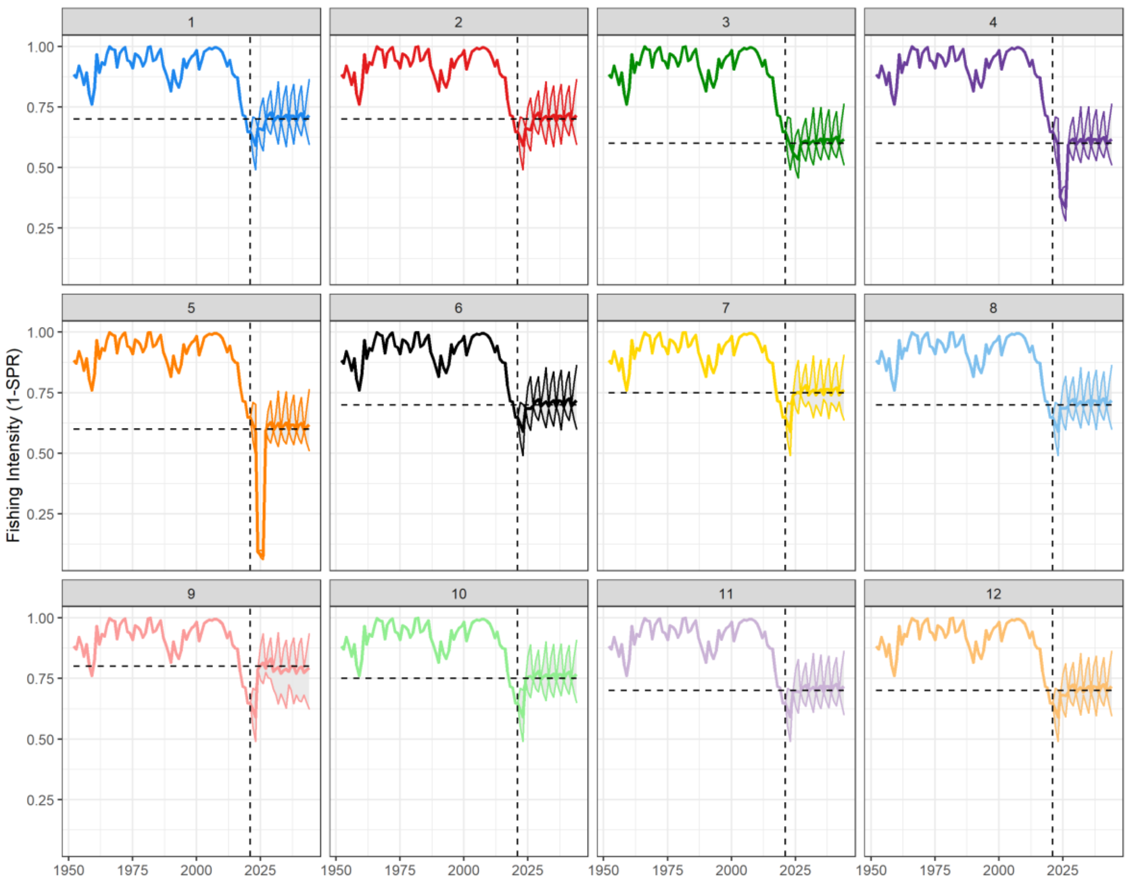

Figure 2. Historical trends in fishing intensity (F, 1-SPR) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median F (thick color line) across all iterations for each harvest control rule (HCR) from the PBF MSE when there was no lag between the end of the operating and estimation models. 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.

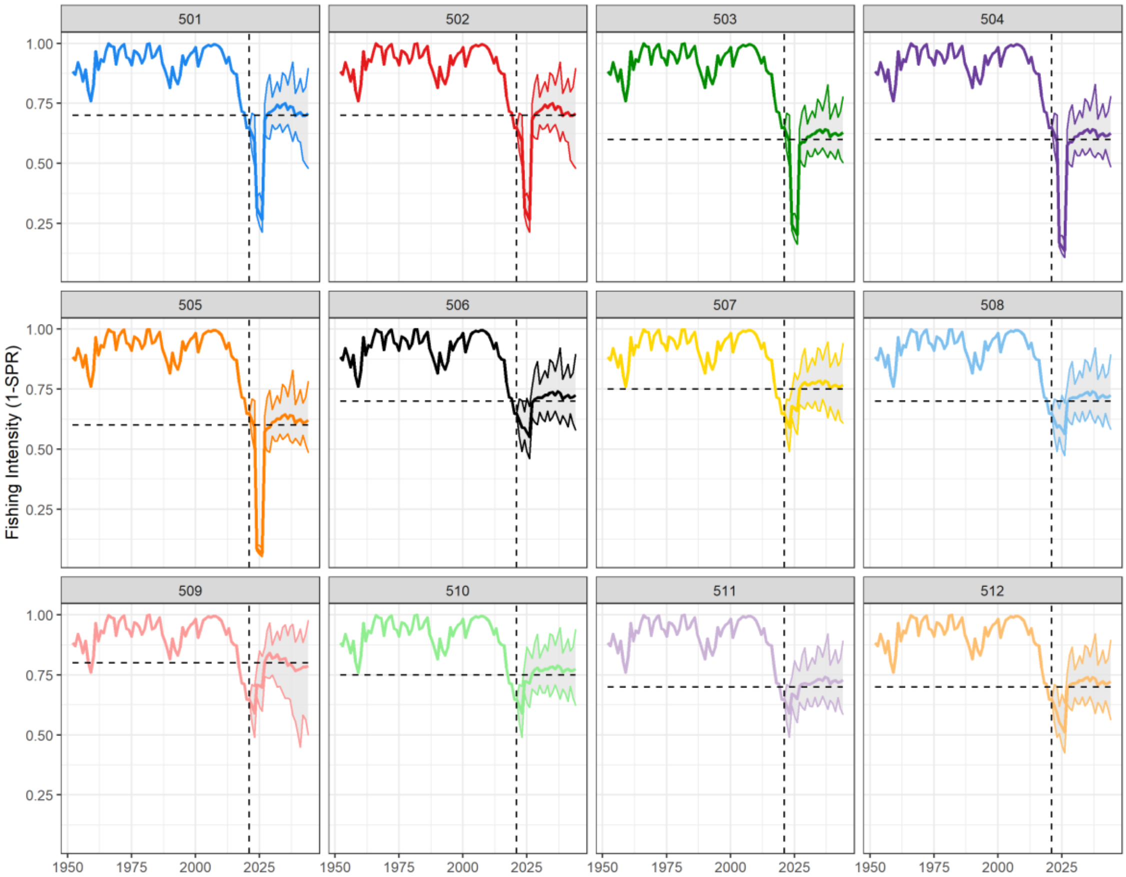

Figure 3. Historical trends in fishing intensity (F, 1-SPR) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median F (thick color line) across all iterations for each harvest control rule (HCR) from the PBF MSE when there is a 1-year lag between the end of the operating and estimation models. 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 501 to 512 to differentiate them from the ones in Figure 2, but the only difference between HCRs is the implementation of the lag in data availability.

The population is growing at the start of the simulation, and the lower F when the lag is implemented results in a faster growing population and median SSB initially overshooting the SSB level associated with the F_{target} and stabilizing at the target level later in the simulation as compared to the no lag runs (compare Fig. 4 and 5). SSB for HCR 9 also appears more variable when there is a lag in data availability. This is the only

HCR which has its threshold reference point the same as the SSB associated with its F_{target}.

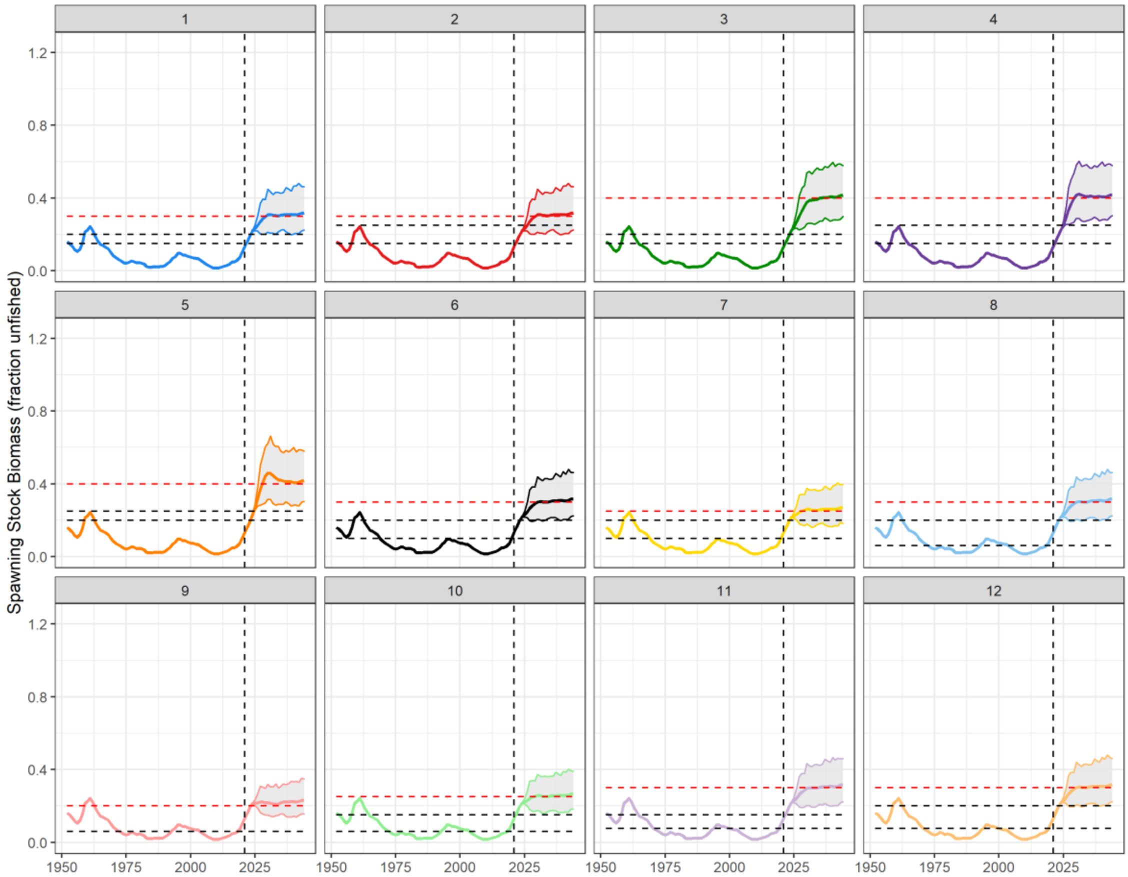

Figure 4. Historical trends in spawning stock biomass (SSB) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median SSB (thick color lines) across all iterations for each harvest control rule (HCR) from the PBF MSE when there was no lag between the end of the operating and estimation models. 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.

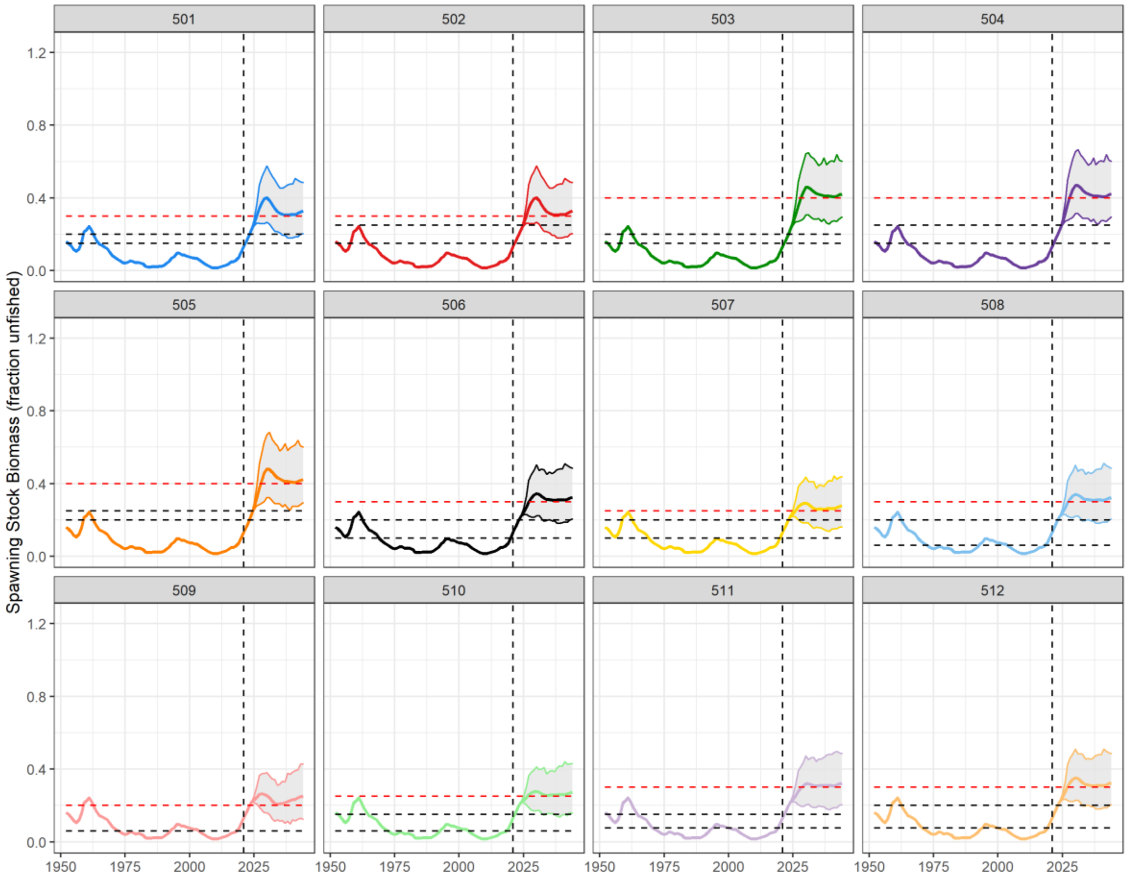

Figure 5. Historical trends in spawning stock biomass (SSB) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median SSB (thick color lines) across all iterations for each harvest control rule (HCR) from the PBF MSE when there was a 1-year lag between the end of the operating and estimation models. 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. Note that HCRs are labelled 501 to 512 to differentiate them from the ones in Figure 4, but the only difference between HCRs is the implementation of the lag in data availability.

When, in addition to the lag in data availability, there is the 25% limit on TAC change between management periods the increase in median F to F_{target} happens more slowly, particularly for HCRs 1 to 5 (Fig. 6), which have an initial drastic drop in F as the estimated 2022 SSB levels breached their LRP. Furthermore, while for most HCRs median F eventually levels off to target levels, median F in the second half of the simulation is quite variable and below target levels for HCRs 1, 2, and 9 (Fig. 6). Finally, as F is reduced to the lowest levels for HCR 5, median F for this HCR only reaches target levels at the end of the simulation (Fig. 6).

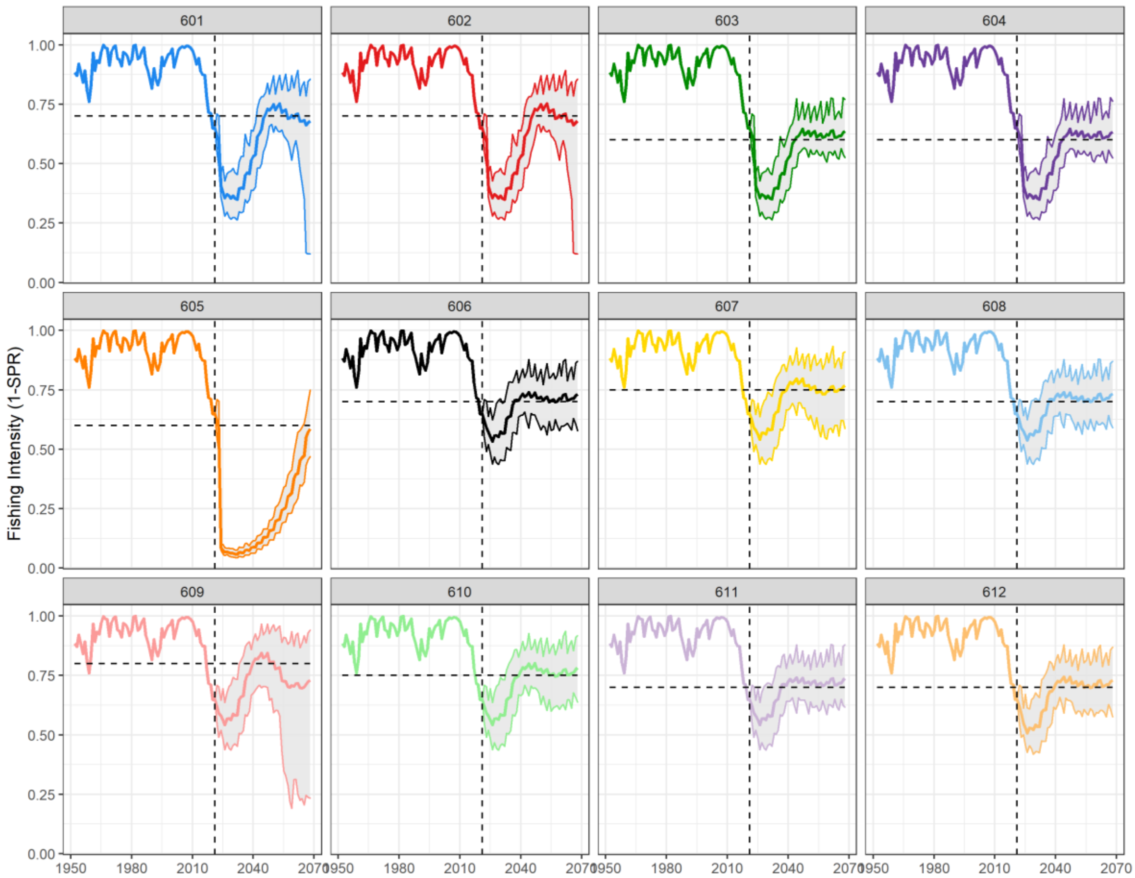

Figure 6. Historical trends in fishing intensity (F, 1-SPR) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median F (thick color line) across all iterations for each harvest control rule (HCR) from the PBF MSE when there is a 1-year lag between the end of the operating and estimation models and a 25% limit on the change in TAC between management periods expect if SSB is below the 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 601 to 612 to differentiate them from the ones in Figure 2, but the only difference between HCRs is the implementation of both the lag in data availability and the 25% limit on TAC changes.

The slow increase in F results in an even faster SSB increase under the 25% TAC limit than when only the data availability lag was applied, resulting in a larger SSB increase over target levels (Fig. 7). For most HCRs, median SSB eventually stabilizes around target levels except for HCR 5, which remains above target levels, and HCRs 1, 2, and 9 which, particularly HCR 9, have larger oscillations induced by the interplay of the delay in management action relative to the end of the simulated assessment and the 25% limit on TAC increase (Fig. 7).

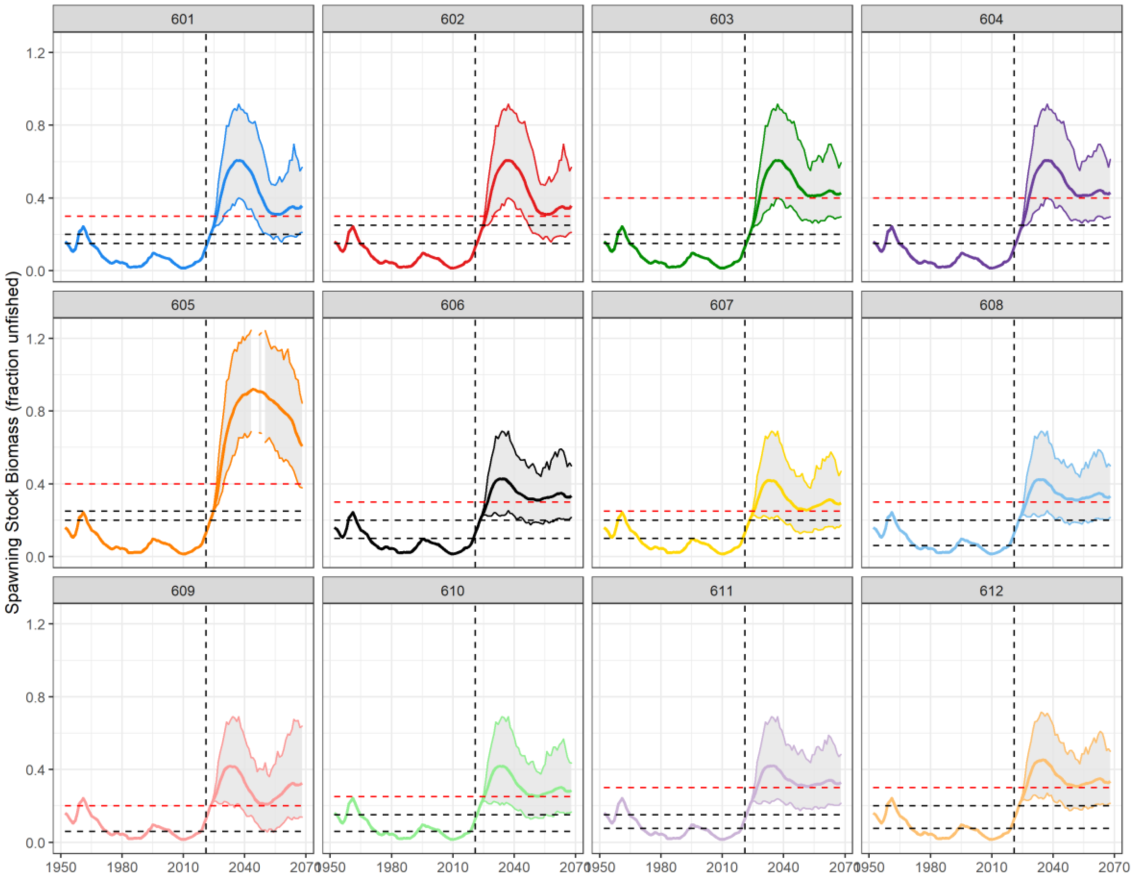

Figure 7. Historical trends in spawning stock biomass (SSB) from the 2022 Pacific bluefin tuna (PBF) stock assessment (ISC 2022) and median SSB (thick color lines) across all iterations for each harvest control rule (HCR) from the PBF MSE when there was a 1-year lag between the end of the operating and estimation models and a 25% limit on the change in TAC between management periods expect if SSB is below the 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 black horizontal dotted lines, while SSB levels associated with the F_{target} are

highlighted as red dotted lines. Note that HCRs are labelled 601 to 612 to differentiate them from the ones in Figure 4, but the only difference between HCRs is the implementation of the lag in data availability and the 25% limit on TAC changes.

As expected given the larger initial drop in F, median catch falls to lower levels initially when the data lag is implemented for HCRs 1 to 5 (compare Fig. 8 and 9). Median catch then increases quickly over levels when no lag present (compare Fig. 8 and 9) following the increase in SSB over target levels (Fig. 5). Median catch for most HCRs then stabilizes in the second half of the simulation (Fig. 9). Note that, as for SSB, catch for HCR 9 is more variable when the data lag is implemented (compare Fig. 8 and 9).

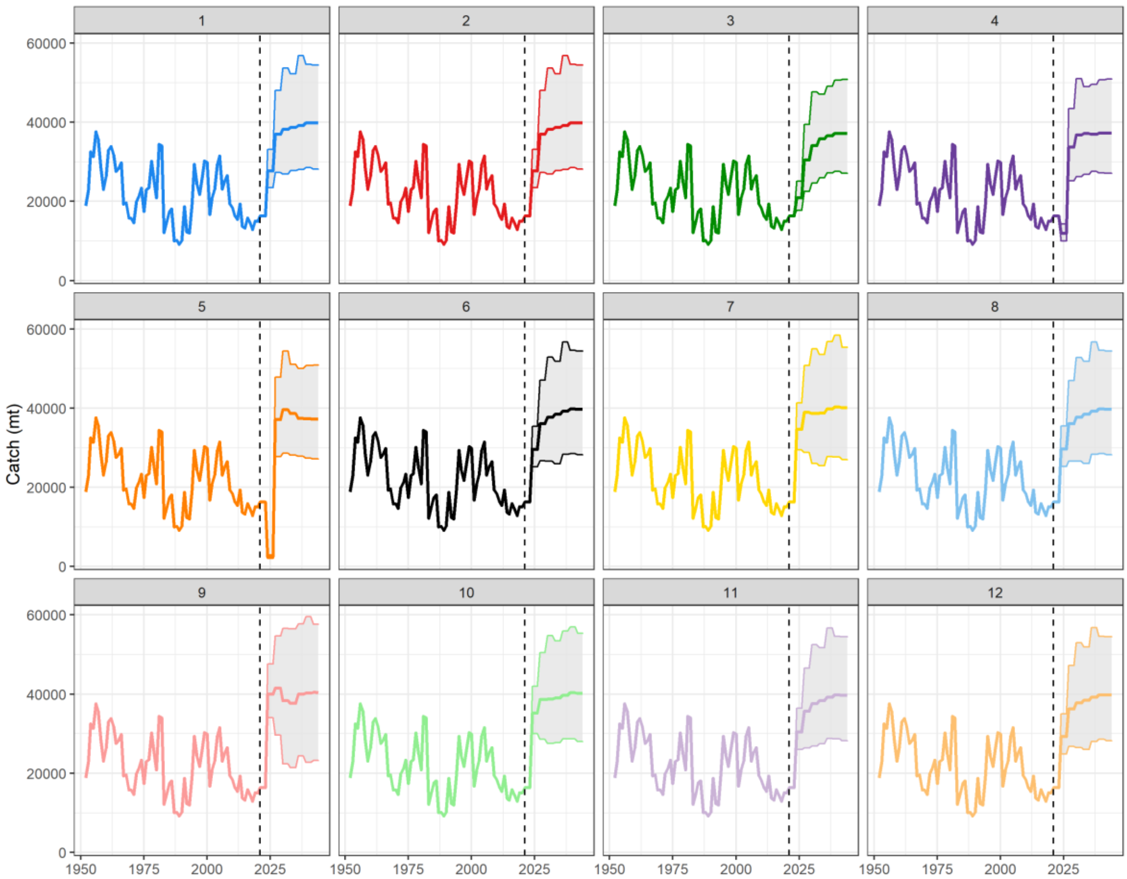

Figure 8. Median catch (thick color lines) across all iterations for each harvest control rule (HCR) from the PBF MSE simulation when there was no lag between the end of the operating and estimation models. The grey shading represents trends in the 5th to 95th quantiles of catch.

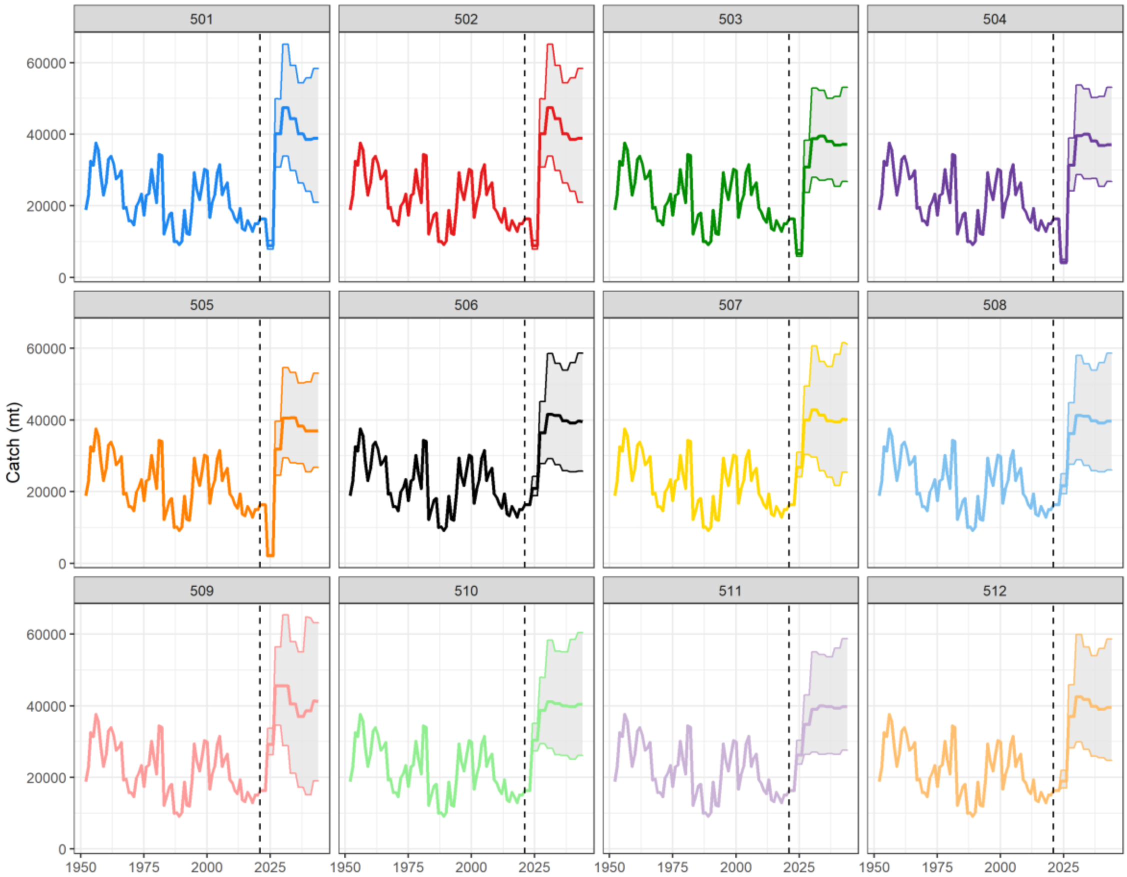

Figure 9. Median catch (thick color lines) across all iterations for each harvest control rule (HCR) from the PBF MSE simulation when there was a 1-year lag between the end of the operating and estimation models. The grey shading represents trends in the 5th to 95th quantiles of catch. Note that HCRs are labelled 501 to 512 to differentiate them from the ones in Figure 8, but the only difference between HCRs is the implementation of the lag in data availability.

When both the data lag and the 25% TAC limit are implemented, median catch increase more slowly from the initial low levels but reaches a higher level (Fig. 10) following the larger initial biomass increase (Fig. 7). For most HCRs, median catch then stabilizes by the end of the simulation, but catch is more variable for HCRs 1, 2, and 9 (Fig. 10) given the higher variability in biomass (Fig. 10).

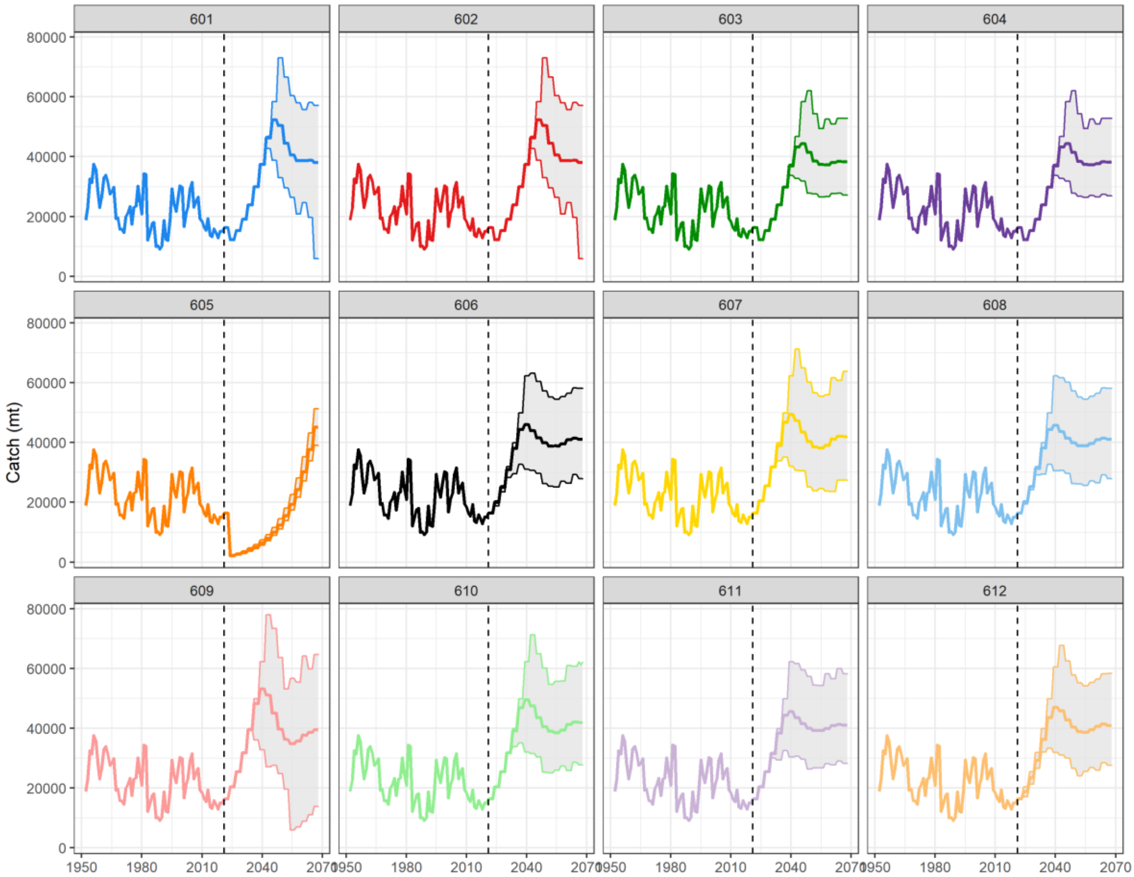

Figure 10. Median catch (thick color lines) across all iterations for each harvest control rule (HCR) from the PBF MSE simulation when there was a 1-year lag between the end of the operating and estimation models and a 25% limit on the change in TAC between management periods expect if SSB is below the LRP. The grey shading represents trends in the 5th to 95th quantiles of catch. Note that HCRs are labelled 601 to 612 to differentiate them from the ones in Figure 8, but the only difference between HCRs is the implementation of the lag in data availability and the 25% limit on TAC changes.

Discussion

We detail and provide links to the R code implementing in the PBF MSE framework the existing lag between data available to the PBF assessment and the application of a management action based on the assessment results. The code was tested in a simulation with and without the 25% limit on TAC changes and works as expected. The associated changes in quantities of management interest are presented allowing evaluation of the impact of the TAC change limit on management objectives.

We show that for the growing PBF population a delay in the detection of the stock having increased above biomass reference points of some HCRs due to the data availability lag leads to biomass increasing to higher levels than when no data lag is present. This increase is amplified further when the 25% limit on TAC changes is implemented. Moreover, for some HCRs, the interplay between delayed stock status estimation and the 25% limit on TAC changes, leads to increased oscillations and higher variability in SSB and catch.

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