Changing Pacific Bluefin Tuna Exploitation Patterns and Implications for Management Strategy Evaluation

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

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

November 2022

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 1 to 8 November 2022, Webinar.

Introduction

The Pacific Bluefin tuna (PBF) MSE framework (Tommasi and Lee 2022) is being developed to help identify potential harvest strategies for managing PBF once it has rebuilt as requested by the WCPFC-IATTC Pacific Bluefin tuna joint working group (JWG). The JWG has specified candidate fishing intensity target reference points (F_{target}) based on spawning potential ratio (SPR). SPR is the equilibrium spawning stock biomass (SSB) per recruit that would result from a specified year(s) biology and the pattern and intensity of fishing mortality relative to the equilibrium SSB per recruit that would occur with the specified year(s) biology and no fishing. When fishing is harder, SPR is lower; thus, fishing intensity is defined as 1-SPR. The candidate harvest control rules (HCRs) proposed by the JWG specify an overall fishing intensity across fleets, but PBF management currently uses catch limits set for specific fleet types based on region (Western Pacific Ocean, WPO, and Eastern Pacific Ocean, EPO) and fish size (WPO small and large fish). The MSE management module thus needs to translate the overall fishing intensity set by a candidate HCR to a Total Allowable Catch (TAC) specific to a fleet type. Furthermore, fleet specific catches are required by the MSE framework to input the TAC set by the management module back into the *dat* file of the operating model (Tommasi and Lee 2022). Currently, the PBF MSE uses the benchmark calculation capabilities of Stock Synthesis (Methot and Wetzel 2013) to search for the F multiplier that produces the specified F_{target} given an exploitation pattern and biology. The F multiplier is used to find the apical F per fleet and season given the relative fishing pattern between fleets (Tommasi and Lee 2022). The apical Fs are then input into the Barnov equation to compute a fleet- and season- specific TAC. The TAC is summed over fleets and seasons to find the overall TAC and a TAC for each management group (see Table 3 in Tommasi and Lee 2022 for how fleets are assigned to fleet types). Thus, the resulting overall TAC and the TAC per fleet and type are dependent on the period chosen to define the exploitation pattern for the equilibrium SPR calculation. The exploitation pattern used in the current MSE framework reflects the most recent period (2017-2019), with the assumption that the recent relative fishing intensity between fleets and seasons will be maintained in the future. Here we examine how PBF catches and catch ratios per fleet type have changed through time and, given the observed temporal variability in relative catch per fleet type, assess the impact of using different exploitation patterns in the MSE management module on the resulting TAC.

Exploitation patterns through time

The relative catch of PBF has fluctuated over time. WPO large fish catch was the dominant source of catches until 1990 (Fig. 1). In 1990 catches of WPO small fish started to increase and dominated catches in the 2000s when the catches of WPO large bluefin tuna fleets declined (Fig. 1). The effect of new management measures on the WPO small fish fleets can be clearly seen by the decline in small bluefin tuna catches since new management measures restricting catches of bluefin tuna < 30 kg were introduced in 2011 (Fig. 1). EPO catch has remained consistent since an increase in the mid-2000s and current catches are more evenly distributed between WPO large, WPO small, and EPO catches (Fig. 1).

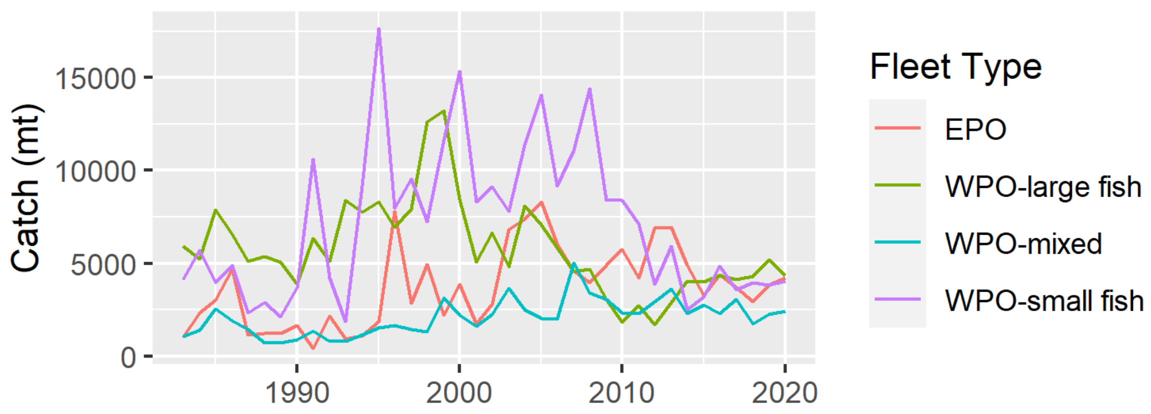

Figure 1. Annual Pacific Bluefin catch from 1983 to 2020 for each fleet type.

Methods

To assess the impact of changing exploitation patterns, we ran the MSE simulation with three different exploitation patterns: 1988-1990, 2002-2004, and 2017-2019. In the first period, catches were dominated by WPO large fish, while in 2002-2004, the largest proportion of catches was WPO small fish, followed by EPO (Fig. 2). In 2017-2019, the proportion of WPO large catches increased relative to 2002-2004 (Fig. 2).

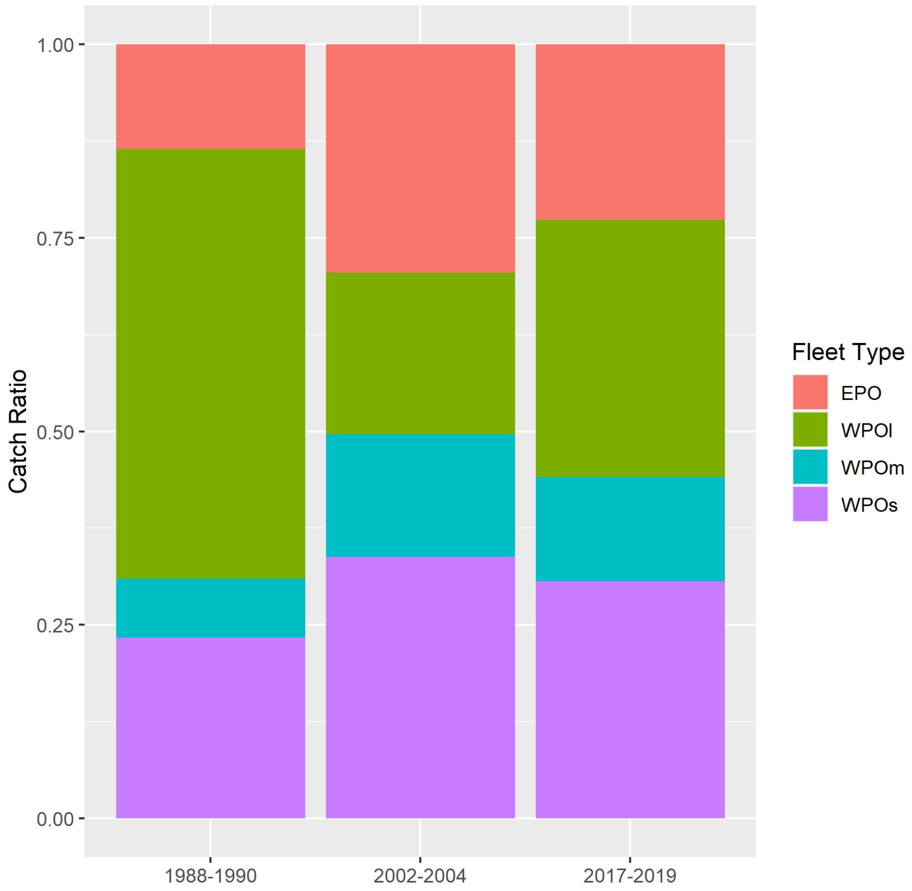

Figure 2. Catch ratios by fleet type for the three different exploitation patterns tested in the MSE simulations.

For this analysis, the MSE simulation was run for 30 years with the base-case operating model (OM) for 25 iterations differing in their random recruitment deviations. The MSE management module used the HCR 15 described in Tommasi and Lee 2022 with a F_{target} of FSPR30%, a threshold reference point of 20%$SSB_{F=0}$, and a limit reference point of 7.7%$SSB_{F=0}$. We assumed no assessment, observation, or implementation error. The only difference between the three simulations was the period specified for averaging relative F and selectivity for the calculation of the F multiplier required to produce an SPR of 30%. For more details about the PBF MSE framework see Tommasi and Lee (2022).

Results

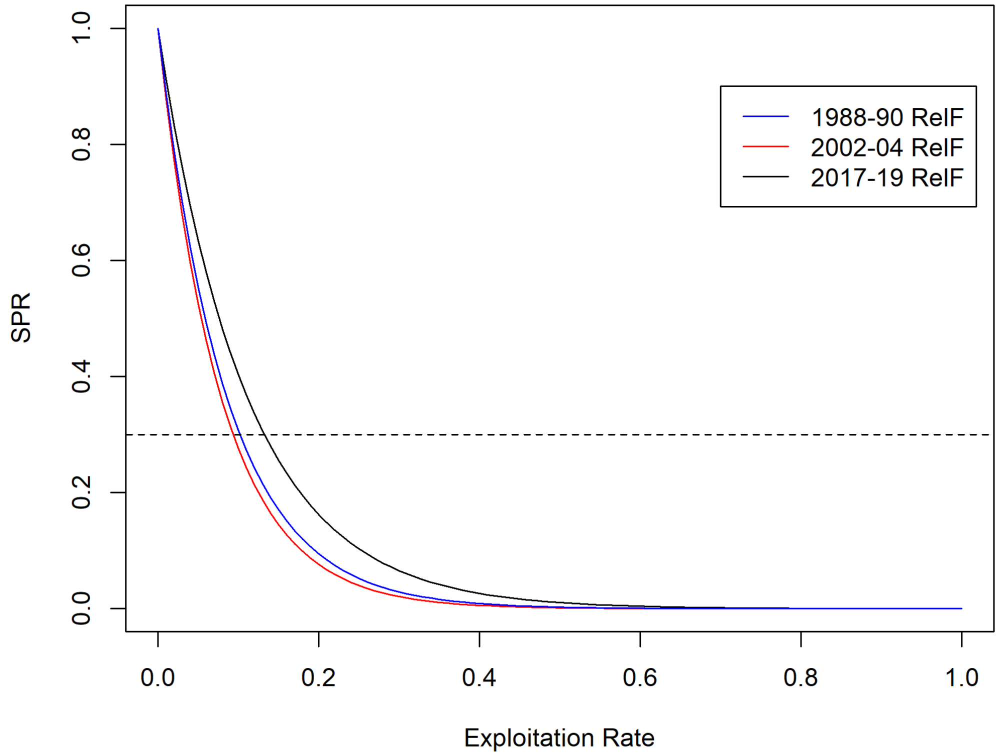

Figure 3. Equilibrium spawning potential ratio (SPR) for different exploitation rates and the three different exploitation patterns. The dotted line represents an SPR of 30%.

Equilibrium SPR calculations under the three different exploitation and selectivity patterns show that there remains more reproductive potential for the same exploitation rate (total catch/summary biomass) under the most recent exploitation pattern (Fig. 3). Therefore, one can fish slightly harder (with a higher exploitation rate) under the most recent exploitation pattern while still producing the same the SPR of 30% specified by the F_{target}. Indeed, the simulation shows that the overall long-term TAC is higher when the MSE management module uses the most recent exploitation pattern (Fig. 4 and Fig. 5).

Figure 4: Worm plots of the Total Allowable Catch (TAC) for individual runs for harvest control rule 15 and the three different exploitation patterns. Each panel presents the results for the labeled exploitation pattern. Trajectories represent separate iterations differing in simulated random recruitment deviates.

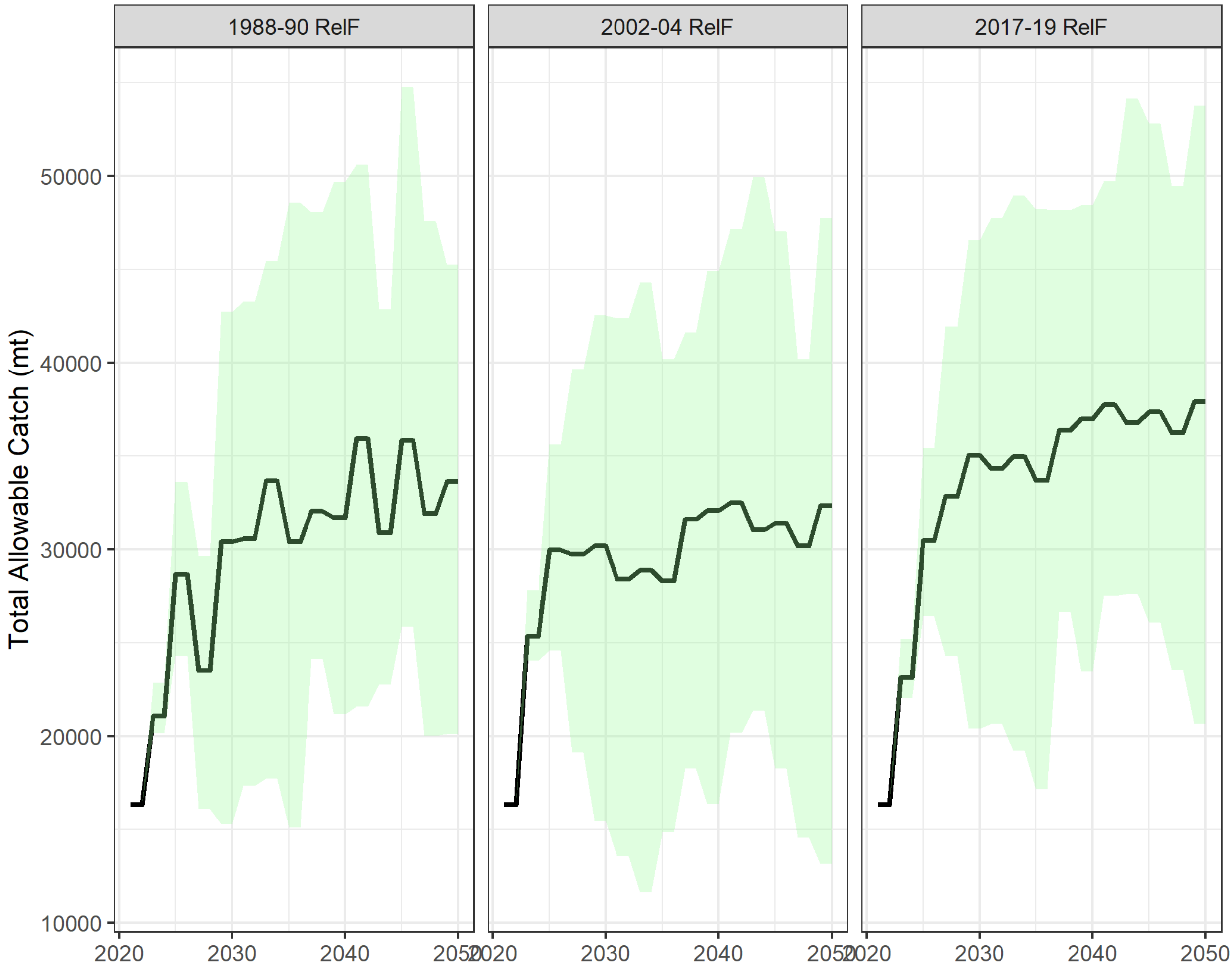

Figure 5: Trends in median Total Allowable Catch (TAC) across all iterations for harvest control rule 15 and each of the three different exploitation patterns. Each panel presents the results for the labeled exploitation pattern. The green shading represents trends in the 5th to 95th quantiles of the TAC.

Furthermore, since the exploitation pattern determines the fraction of the total fishing intensity assigned to each fleet, TAC by fleet type varies substantially between the different patterns tested (Fig. 6 and 7). For instance, while the overall TAC is lowest for the 2002-2004 exploitation pattern, EPO catches are highest (Fig. 6). By contrast, the WPO TAC is highest under the 1988-1990 exploitation pattern (Fig. 7).

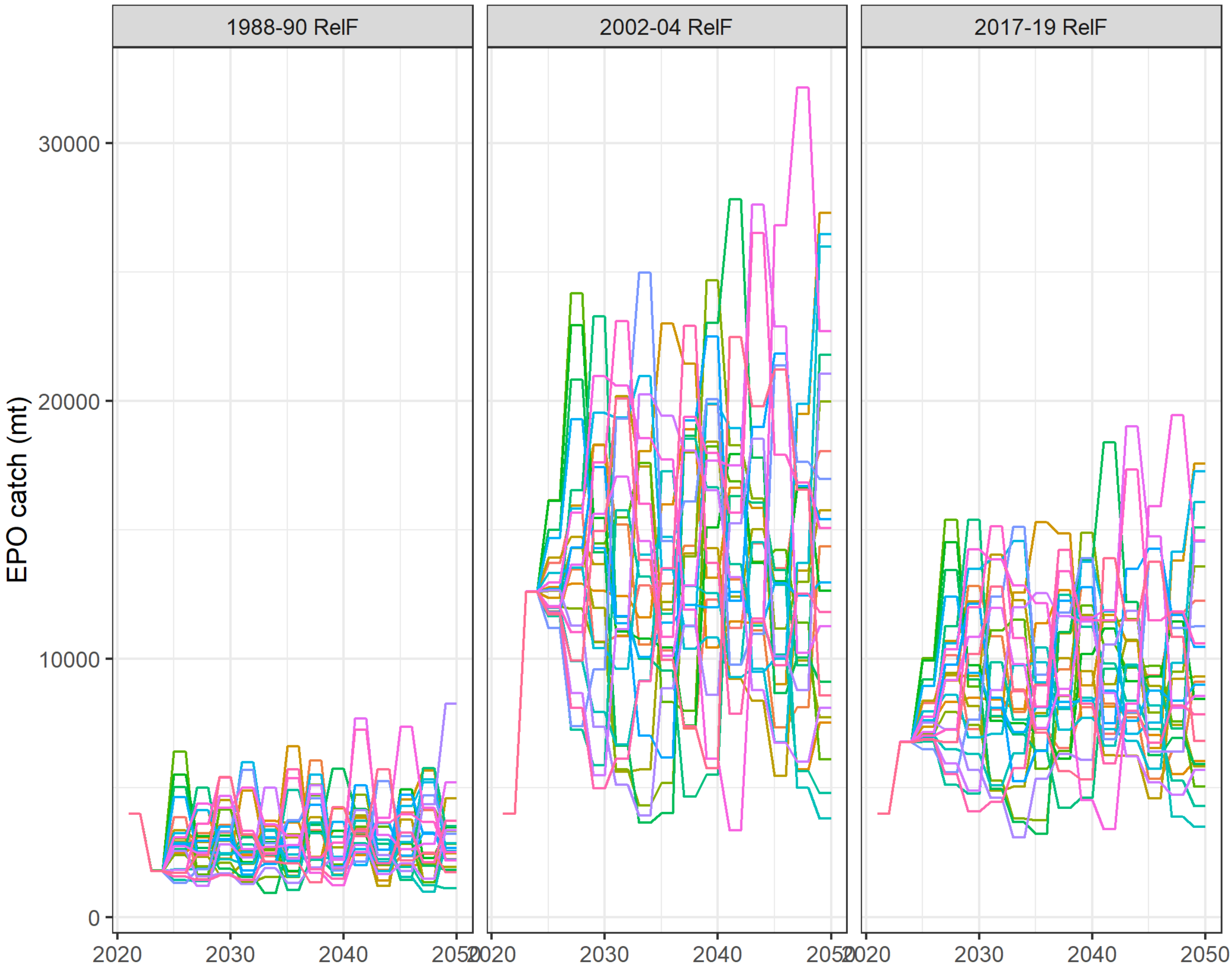

Figure 6: Worm plots of the EPO Total Allowable Catch (TAC) for individual runs for harvest control rule 15 and the three different exploitation patterns. Each panel presents the results for the labeled exploitation pattern. Trajectories represent separate iterations differing in simulated random recruitment deviates.

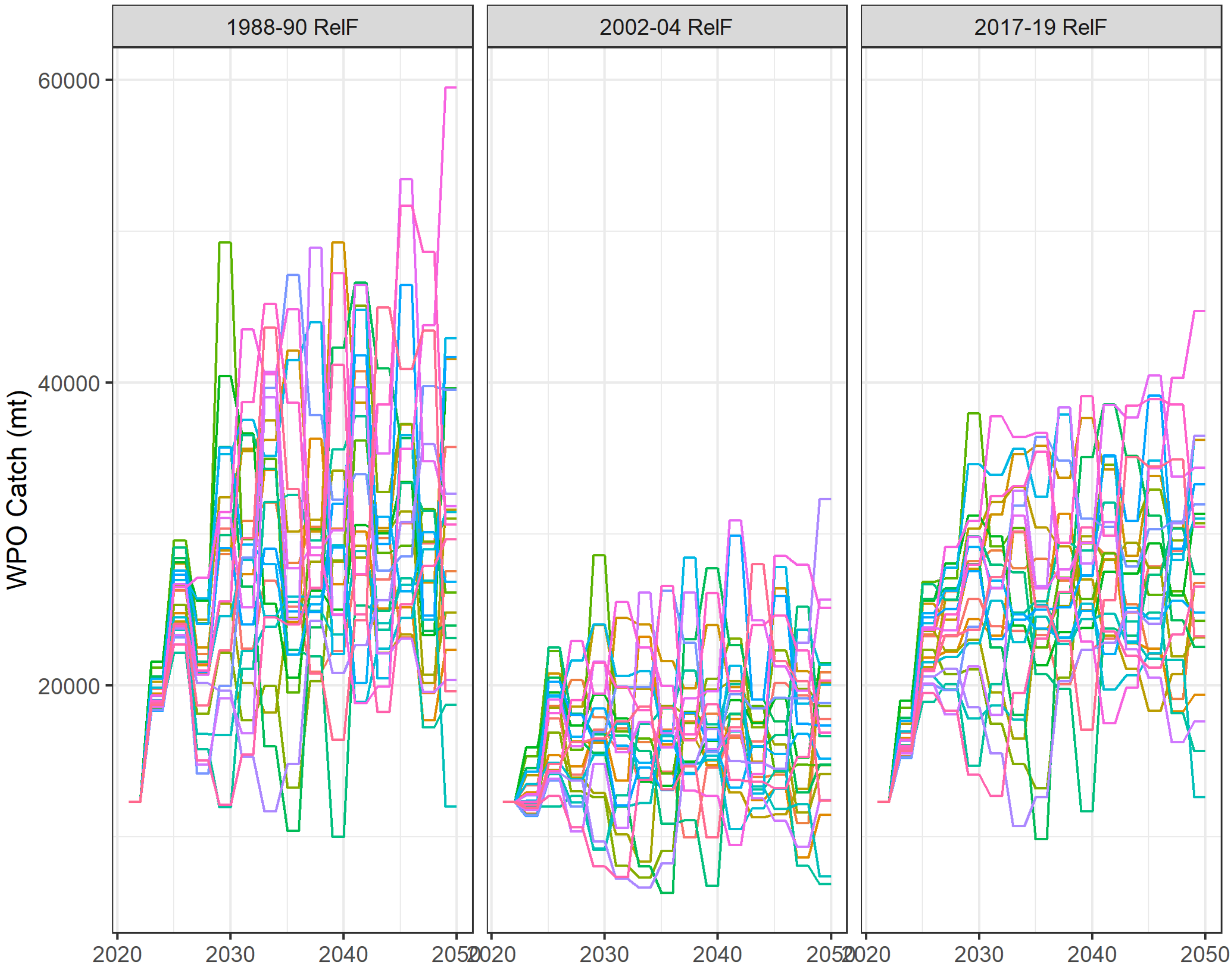

Figure 7: Worm plots of the WPO Total Allowable Catch (TAC) for individual runs for harvest control rule 15 and the three different exploitation patterns. Each panel presents the results for the labeled exploitation pattern. Trajectories represent separate iterations differing in simulated random recruitment deviates.

The choice of exploitation pattern was also found to impact SSB trends. Exploitation pattern 2002-2004 resulted in the lowest long-term median SSB (Fig. 8), even if it was associated with the lowest TAC (Fig. 5), likely because of the higher fraction of small fish targeted under this pattern. The 1988-1990 exploitation pattern, which targeted a higher fraction of large fish, resulted in the highest long-term median SSB (Fig. 8).

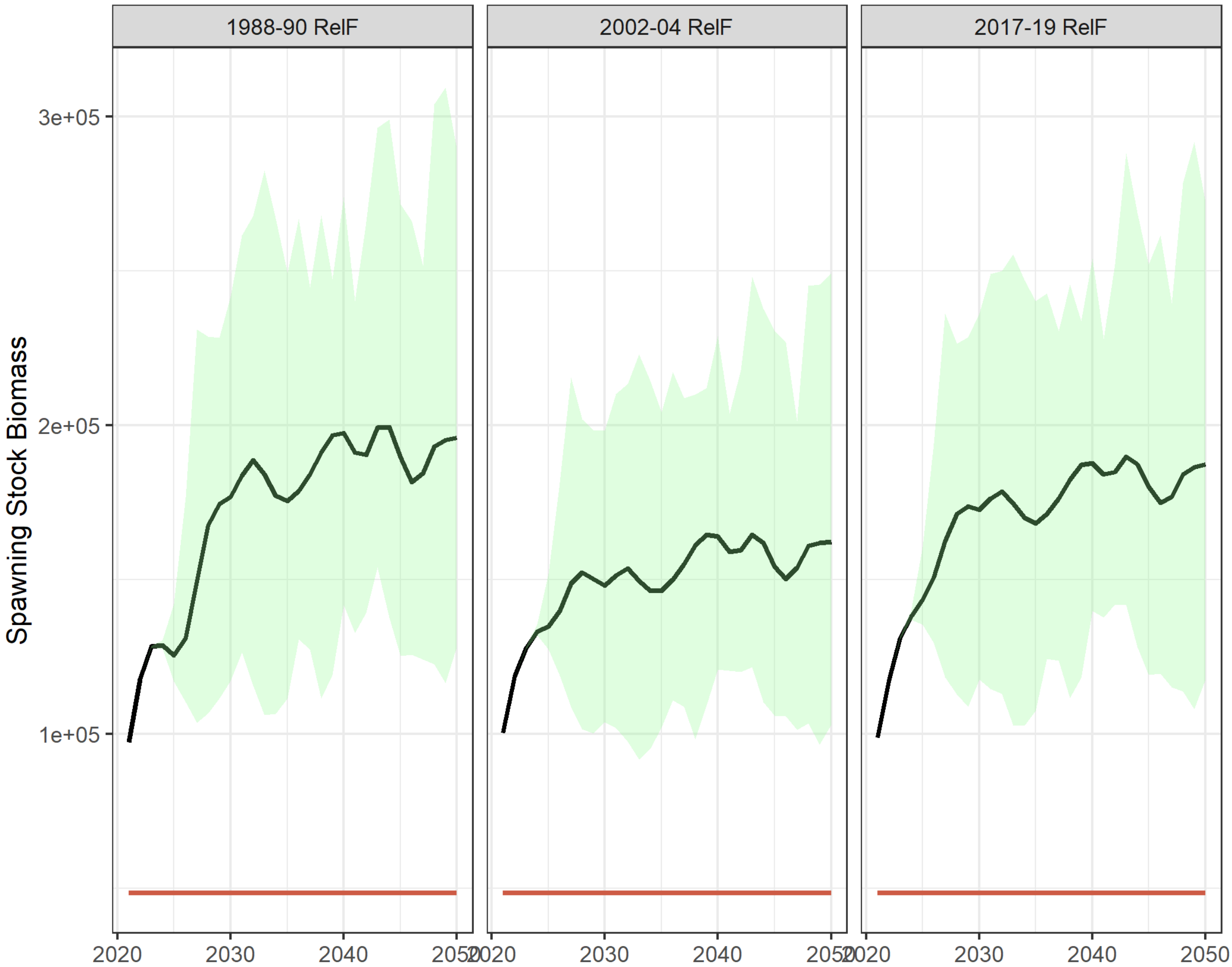

Figure 8: Trends in median spawning stock biomass (SSB) across all iterations for harvest control rule 15 and each of the three different exploitation patterns. Each panel presents the results for the labeled exploitation pattern. The green shading represents trends in the 5th to 95th quantiles of the SSB. The red line represents the limit reference point of 7.7% of unfished SSB.

Conclusion

We demonstrate that the choice of the range of years over which to average the relative F between fleets and seasons and the selectivity for the F_{target} calculations in the PBF MSE management module can lead to a different performance in terms of both biomass and catch metrics. We suggest the WG select an averaging period that is kept consistent across all the HCRs to be tested in the MSE. Assuming that the most recent 2017-2019 exploitation pattern with a lower relative F for fleets targeting small fish is maintained in the MSE simulation might be the most realistic option considering the current CMM. This option also results in the highest overall TAC for a given F_{target}, and a higher SSB than the 2002-2004 pattern. It will also be important to communicate to the JWG the impact of this assumption when presenting MSE results.

References

Tommasi, D., and Lee, H. 2022. Overview of the preliminary Pacific bluefin tuna management strategy evaluation framework. ISC/22/PBFWG-2/05.