

Revision of future projection software SSfuture C++.¹

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¹This working paper was submitted to the ISC Albacore Working Group Intercessional Workshop, 21-27 March 2023, held at the National Oceanic and Atmospheric Administration Southwest Fisheries Science Center, La Jolla, California, USA.

Abstract

This working paper outlines the specifications of SSfuture C++, a software designed for the future projection of the fish stock. Its application will be utilized during the ISC North Pacific Albacore tuna stock assessment in 2023. The SSfuture C++ underwent various updates to cater to the ISC Albacore Working Group (ALBWG) needs for the albacore stock assessment. The primary changes include the capability to modify the fishing mortality at age every year and the inclusion of estimation errors from Stock Synthesis 3 to account for uncertainties in the initial values. The uncertainties considered are the number at age, F multiplier, R0, and SSBO. Moreover, the dynamic B0 ($SSB_{F=0}$) for all future projection runs was calculated using R0, SSBO, and recruitment deviation. The accuracy of future projections has considerably improved compared to the previous stock assessment. However, the estimation errors for selectivity and recruitment deviation are to be considered and require further development.

Introduction

The ISC Albacore Working Group (ALBWG) has used future projection software SSfuter C++ in the 2020 North Pacific Albacore stock assessment (Ijima 2019). In the 2023 stock assessment, the ALBWG has agreed on some modifications to the program, including:

1. Using the "ss.cor" file output of Stock Synthesis 3 to generate initial values for the simulation.
2. Explore why the uncertainty in the preliminary run of the uncertainty range is smaller from year to year.
3. Allowing future projections to change fishing mortality (F) by year (SSfuture C++ previously had a constant F and constant catch option only).
4. Dynamic B0 ($SSB_{F=0}$) generated from the Multivariate Normal (MVN) distribution used to predict future depletion rates.

This working paper addressed these modifications and future projections based on scenarios determined during the ALBWG discussions. The depletion rate for the average total biomass from 2006-2015 was also predicted.

Material and methods

Update the SSfuture C++

We updated the SSfuture C++ program option requested in the ALBWG workshop. This update allows for the consideration of implementation errors in future projections.

Initial values for the future projection

The ALBWG noted that the confidence interval of the future SSB became smaller annually in the previous stock assessment. Focusing on the uncertainty configuration, only the number at age was considered for the uncertainty of initial values in the last stock assessment. However, the previous projection did not account for the fact that fishing mortality should be lower when there are more fish and higher when there are fewer fish. During the current stock assessment, selectivity was fixed at all initial values, an F

multiplier corresponding to the initial number at age was computed, and a preliminary analysis was performed. However, the trend toward smaller widths of confidence intervals still needs to be eliminated. Thus, we also consider the uncertainties of R_0 and SSB_0 as further initial values and different spawner-recruitment curves by initial condition were applied to future projections.

Comparison with the reference point

The management objective is to maintain the total biomass around the 2006-2015 average, and the biological limit reference point for the North Pacific albacore is $14\%SSB_{F=0}$. Therefore, $SSB_{F=0}$ corresponding to each projected future run was calculated using R_0 and recruitment deviation to compare the limit reference point. The recruitment in year t in the absence of fishing mortality is $R_t = R_0 \exp(\text{dev}_t - 0.5 \times \text{sigma}R^2)$. The dev_t for the stock assessment period considers the bias adjustment. On the other hand, in the period for future projections, a random variable with $\text{sigma}R = 0.46$ was used. $SSB_{F=0}$ was calculated by recruitment and natural mortality in all projections. $14\%SSB_{F=0}$ was aggregated by year, and each year's annual depletion rate was calculated. For example, the depletion rate for the 2025 limit reference point is $SSB_{2025} / 14\%SSB_{F=0,2025}$. The depletion rate for total biomass was also calculated using the total biomass corresponding to the initial value as the denominator.

Future projection scenarios

Future projections were conducted under two scenarios: 1) a constant F scenario for 2018-2020 and 2) a random F scenario. The random F was resampled by historical fishing mortality from 2005 to 2019.

Stochastic simulation

In these scenarios, 400 initial values were generated by MVN, and 400-time iterations were addressed with each initial value for a total of 16,000 simulations. Results were averaged by each year, and 60% and 95% confidence intervals were calculated from the standard deviation.

Result and discussion

The MVN distribution generated the F multiplier and spawn-recruitment curves corresponding to initial values with different stock conditions. As a result, issues that narrow the uncertainty range from year to year were largely solved. using the F multiplier and spawn-recruitment curves in MVN corresponding to initial values with different stock conditions (Figure 1a, Figure 2a). Furthermore, calculating $SSB_{F=0}$ for all runs allowed for a more accurate calculation of whether the biological limit reference point will be reached in the future (Figure 1c, Figure 2c, Figure 3). There was no large differences in results between the constant and random fishing mortality scenarios. (Figure 1, Figure 2). The reason was that the average $F_{\%spr}$ values were close (Figure 1b, Figure 2b). $F_{\%spr}$ was lower in both scenarios than the target, and the probability of the total biomass exceeding the target level is between 50% and 80% (Figure 1b d, Figure 2b d). The probability of being below the limit reference point in the future is very low in both scenarios (Figure 1c, Figure 2c). This update to `SSfutureC++` allows for a more seamless connection between the Stock Synthesis 3 results and the future projection results. However, this update did not account for age selectivity and estimation errors of recruitment deviation, which should be included for future development.

References

Ijima, H., 2019. Update of future projection program `SSfuture C++`. ISC/19/ALBWG-02/07

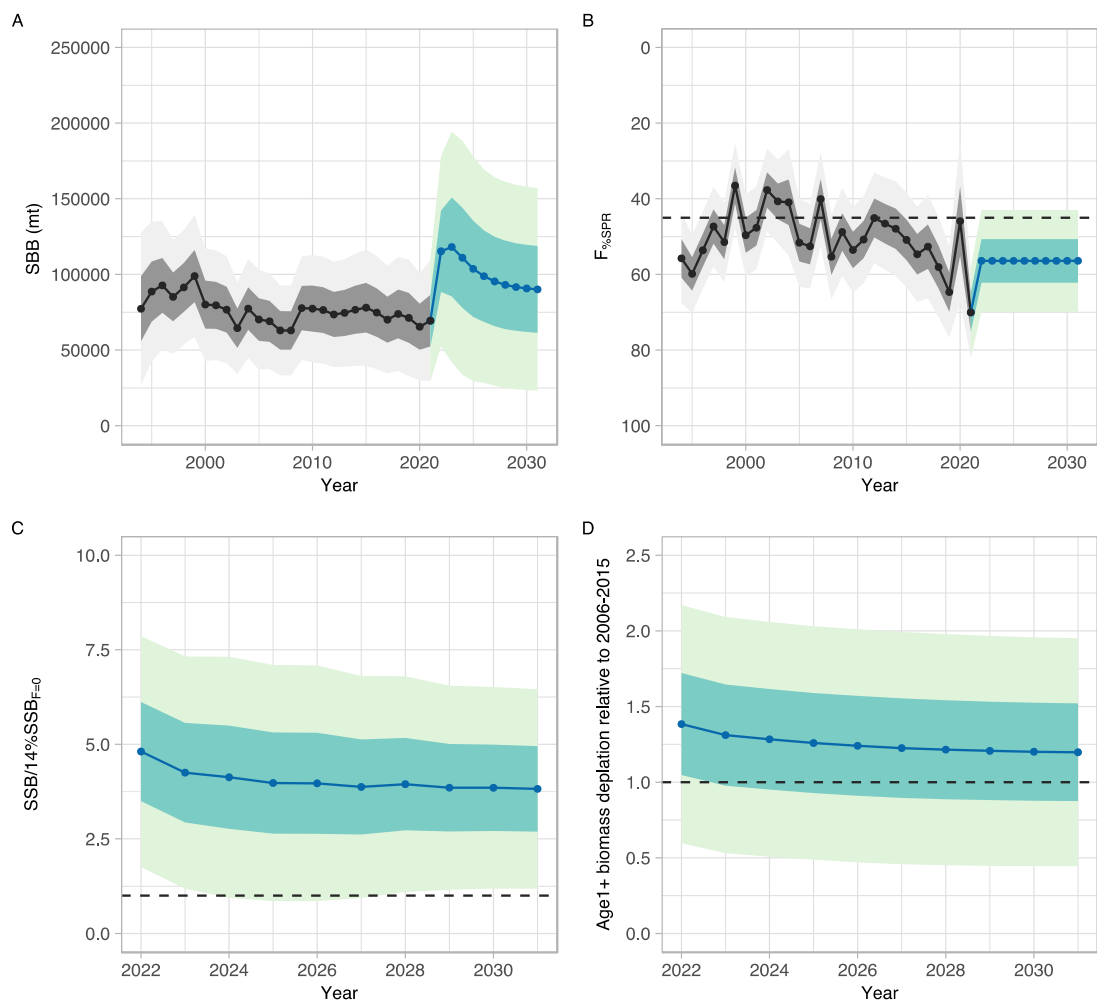


Figure 1. Future projection results of constant F scenario for 2018-2020 average. Solid lines denote mean values, uncertainty ranges indicate 60% and 95% confidence intervals, and the dashed lines are the reference points. A: Annual changes in Spawning Stock Biomass (SSB). B: Interannual changes in fishing mortality ($F_{\%SPR}$). C: Projected ratios to the limit reference point thresholds ($14\%SSB_{F=0}$). D: Projected ratios to management targets for the total biomass.

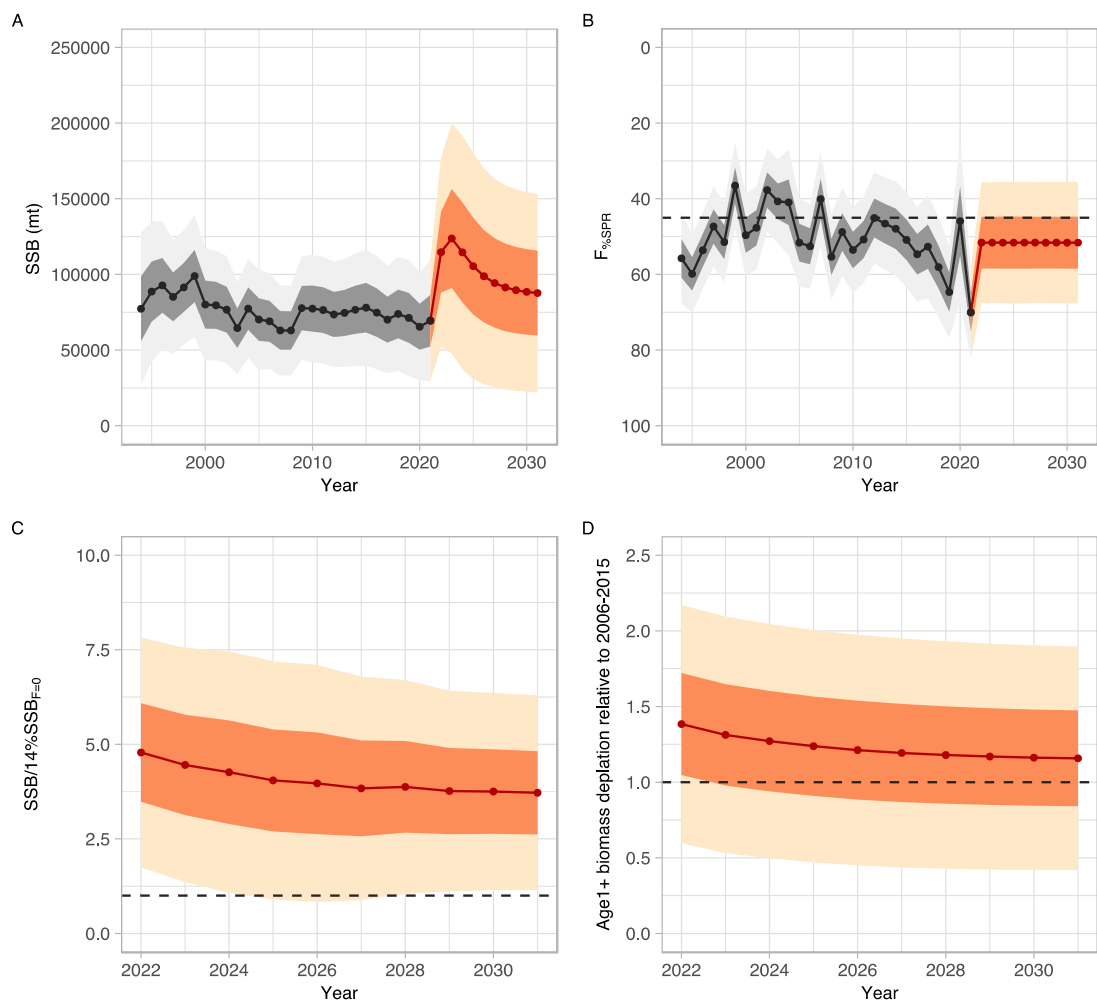


Figure 2. Future projection results in a random F scenario (resampling from 2005 to 2019). Solid lines are mean values, uncertainty ranges denote 60% and 95% confidence intervals, and the dashed lines are the reference point, respectively. A: Annual changes in Spawning Stock Biomass (SSB). B: Interannual changes in fishing mortality ($F_{\%SPR}$). C: Projected ratios to the limit reference point thresholds ($14\%SSB_{F=0}$). D: Projected ratios to management targets for the total biomass.

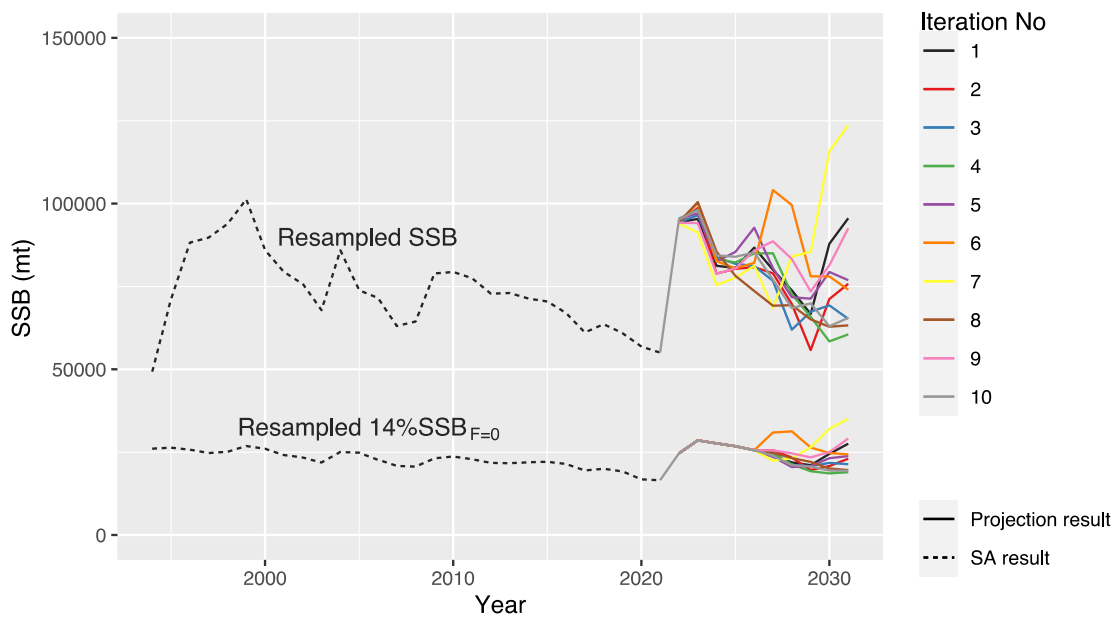


Figure 3. A future projection result using one of several initial population conditions. This example projection involved running ten iterations with a random F scenario. The SS3 "ss.cor" file gave the initial values and generated random numbers according to the multivariate normal distribution, and the generated Spawning Stock Biomass (SSB) correlated to Dynamic B0 ($SSB_{F=0}$). Future projections vary annually for each run. Thus, it was assumed that the $SSB_{F=0}$ in the future projection period also varied. For the final future projection, 400 initial values were created, and each simulation had 400 iterations, producing 16,000 results.