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Uncertainties of future projection in North Pacific albacore tuna stock assessment.[1]

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Abstract

This study presents adjustments to the future projection program (SSfuture C++) required to conduct the North Pacific albacore tuna stock assessment. First, a comparison was made with the latest SS3 (SS3 V3.30.20) future projection results, and second, the handling of uncertainty was explored. Uncertainty attempted to account for process errors in recruitment and variation in initial values of number at age and fishing mortality at age. Comparing the results of the deterministic future projection, the results of SSfuture C++ and SS3 3.30.20 were in perfect agreement. Uncertainty in the initial value of the number at age could be created by assuming a multivariate normal distribution using the variance-covariance matrix output by SS3. However, several alternatives are proposed since no variance-covariance matrix is available for fishing mortality at age.

Introduction

The ISC Albacore Working Group (ALBWG) conducted a North Pacific albacore tuna stock assessment in 2020 (ISC 2020). This stock assessment used a proprietary population dynamics program, the SSfuture C++ (Ijima 2019). Using SSfure C++, the ALBWG implemented the constant catch and the constant fishing mortality scenario considering uncertainties that were the initial number at age and process errors of fish recruitment. However, the 95% confidence interval of the constant fishing mortality scenario was smaller and less realistic from year to year. The reason was considered that the same fishing mortality at age was used for all runs. For instance, for 1,000 simulations, an initial population with variation in a multivariate normal distribution was obtained. These initial values can vary from a large number of fish to a small number of fish, to being close to the average, and so on. Suppose these initial populations are multiplied by constant fishing mortality. In that case, the number of catches will be over-calculated for runs with larger initial populations than the average. The number of catches will be under-calculated for runs with initial populations smaller than the average. The number of catches in the initial condition should be the same for all conditions. Therefore, for accurate future projections, fishing mortality at age must also calculate according to initial populations. On the other hand, to conduct a consistent stock assessment, it is necessary to match the behavior of the latest version of SS3 with SSfuture C++ because SS3 is being improved daily, and the format of the outputs and the assumption of population dynamics are changing.

This paper first compares the future projection results of the latest SS3 (3.30.20) and SSfuture C++ versions to check for any problems. Next, some initial settings were created for the stochastic future projection, and a preliminary future projection was performed.

Material and methods

Simple test run

A simple test run compared the future projection results of the latest SS3 and SSfuture C++ versions. This test run used SS3 V3.30.20. The input data were those used in the 2020 stock assessment. The version SSfuture C++ was ssfcpp20191125.cpp. The scenarios used average fishing mortality for 2015-2017, and deterministic future projections were run for ten years.

Test runs with uncertainties.

Fishing mortality at age must be set to correspond to the initial population number variance to ensure uncertainties in future projections. The number at age was generated using the variance-covariance matrix output by SS3 to generate random numbers according to multivariate normal distribution. The estimated sigma R (0.3) in the 2020 stock assessment was used for the recruitment process error. The seasonal (*s*) fishing mortality at age (*a*) was set for each fleet (*f*) as follows.

$F_{f,s,a} = Fmulti \times f_{f,s} \times Asel2_{f,s}$,

where *Fmulti* is the overall fishing mortality multiplier used to calculate MSY and SPR. The $f_{f,s}$ is the seasonal fishing mortality coefficient by the fleet. The $Asel2_{f,s,a}$ is organized by season and fleet and is calculated from size selectivity and age selectivity.

SS3 outputs the variance-covariance matrix of $Asel2_{f,s}$ but only for the first season. If we obtain the variance-covariance matrix of $Asel2_{f,s}$ for each season, we could use the random numbers according to multivariate normal distribution to create more accurate initial values. We, however, conducted the following test run to examine alternatives because this is unlikely to be available this time.

1. AgeSel_adjust

Age selectivity $Asel2_{f,s,a}$ was adjusted by a multiplier so that the initial number of fish caught was equal in all runs. The multiplier does not change with the season. Using the adjusted $Asel2_{f,s,a}$ 500 initial values were created, and each run was simulated for 1,000 trials for a total of 500,000 results.

2. AgeSel_Qt1

The future projection was addressed using *Asel2* for the first quarter only because given that the variance-covariance matrix of *Asel2* is only available for the first quarter. Specifically, it replaced the *Asel2* of the first quarter with selectivities of other seasons and performed deterministic future projections.

3. Fmulti_adjust

A multiplier adjusted *Fmulti* to equal the initial catch numbers for all runs. Same as with the AgeSel_adjust test, the adjusted *Fmulti* was used to create 500 initial values, each simulated for 1,000 trials, with a total of 500,000 results tabulated. This test run was done assuming that age selectivity was not changed in all runs.

The period for future projections was set for ten years, and the period for averaging fishing mortality coefficients is consistent with 2015-2017.

Result and discussion

The output of SS3, Asel2, is calculated from the size selectivity and age selectivity within SS3, and the conversion of size selectivity to age involves seasonality. Thus, the value changes each season (Figures 1 and 2). Asel2, Fmulti, and $f_{f,s}$ gave fish mortality at age for each fleet (Figures 3 and 4). Comparing the deterministic future projection results of SS3 and SSfuture C++, the population trajectories were in perfect agreement (Figures 5 and 6). The SSfuture C++ program is consistent with SS3. Thus SSfuture C++ does not need to be modified.

The mean future projection that Asel2 adjusted to equal the other initial number of fish caught, resulting in lower spawning stock biomass than the deterministic future projection for SS3 (Figure 7). This test run uses highly reproducible initial catch at age, but fishing mortality at the age that differs most significantly from the SS3. This adjustment may not be suitable for future projections.

When Asel2 in the first season was fixed for the other season, spawning stock biomass showed lower than the SS3 result (Figure 7). This may be due to the Japanese pole and line fishery (F21), which exhibits the highest fishing pressure (Figures 3 and 4). F21 operates in the second quarter, but the test used the highest Asel2 of the first season. Thus it overestimates the fishing mortality of F21, resulting in a lower calculation of future abundance (Figures 1 and 2).

When Fmulti was adjusted to match the initial number of fish caught, the stochastic future projections generally matched the results of the deterministic future projections for SS3 (Figure 7). The maximum difference between the two results is 1.6%, and the 95% confidence interval shows that the range is generally the same over the ten years, eliminating the problems identified in the 2020 stock assessment (Figure 8).

Conclusion and suggestion

- Using SSfutureC++ for stock assessment should not be problematic based on the deterministic future projection results.
- Once the seasonal Asel2 variance-covariance matrix is obtained, a better initial value can be created.
- However, at this point, the initial fishing mortality at age needs to be adjusted in some way.
- The test run results showed that adjusting Fmulti was better. However, intuitively, adjusting Asel2 seems to be more consistent with SS3.
- In the stock assessment, the results adjusted for Fmulti and Asel2 are calculated and compared again.

References

ISC 2020. Stock assessment of albacore tuna in the North Pacific ocean in 2020. ISC/20/ANNEX/12

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

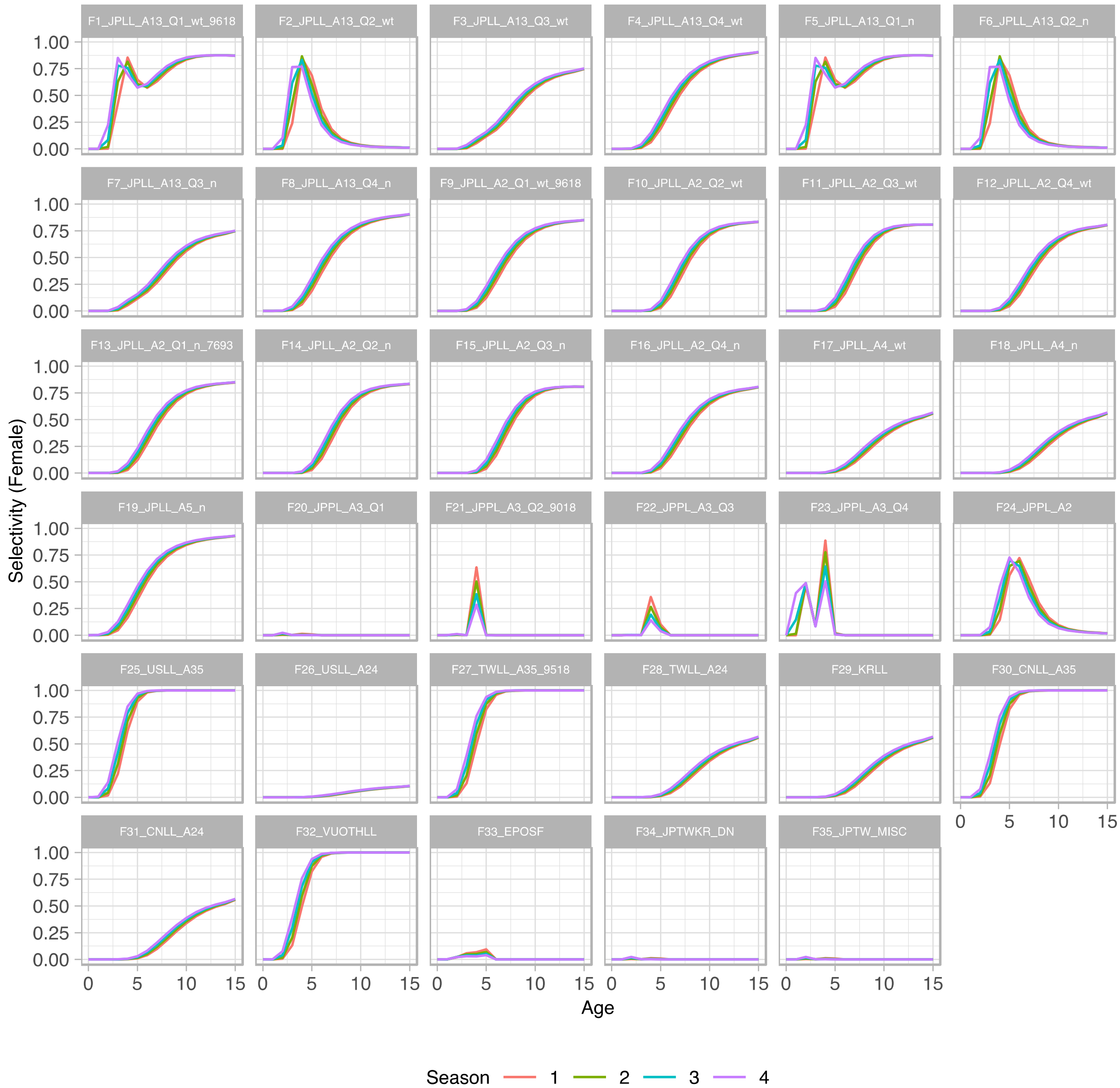

Figure 1. SS3 output of female age selectivity (Asel2).

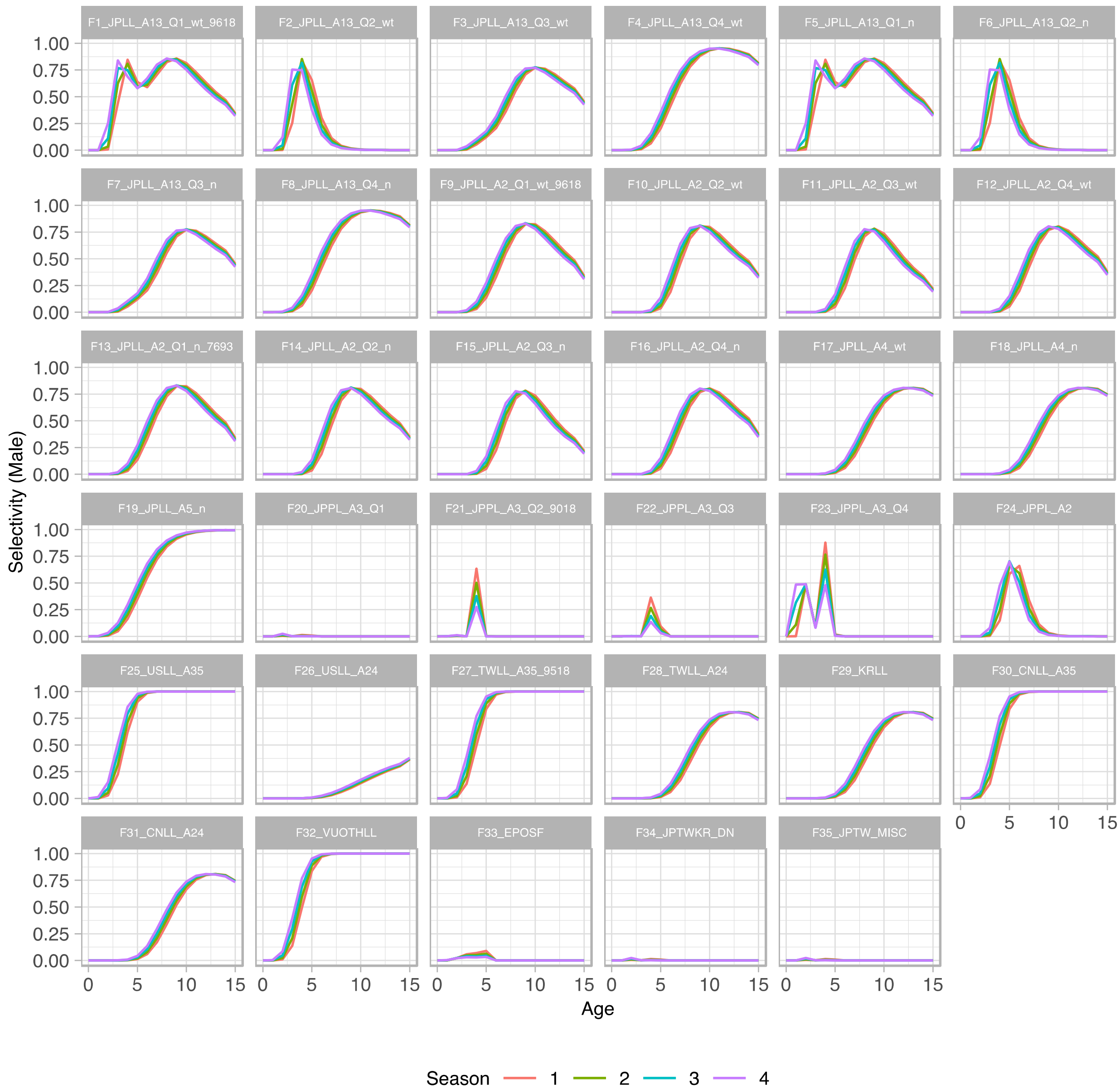

Figure 2. SS3 output of male age selectivity (Asel2).

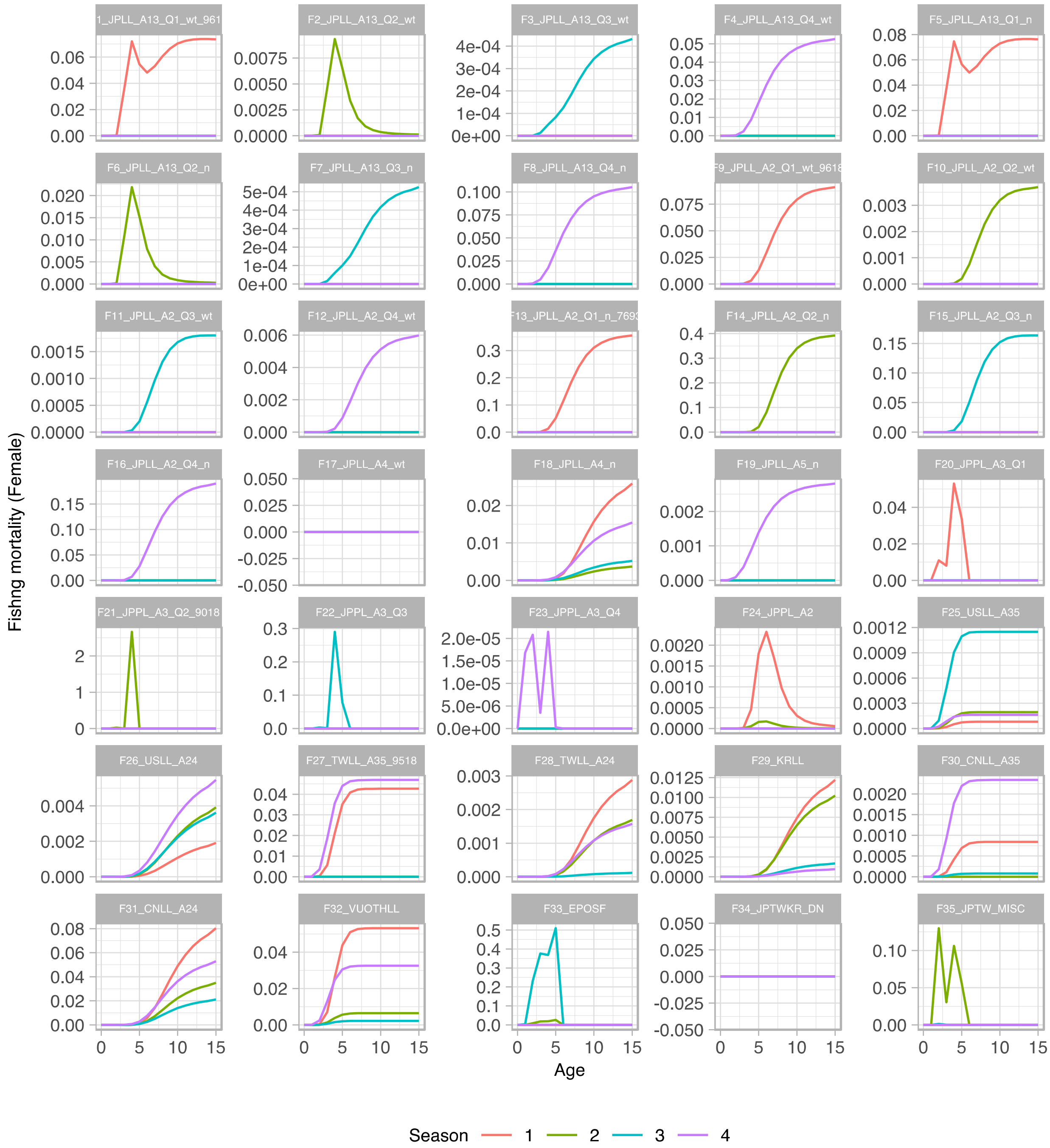

Figure 3. Female fishing mortality at age by season.

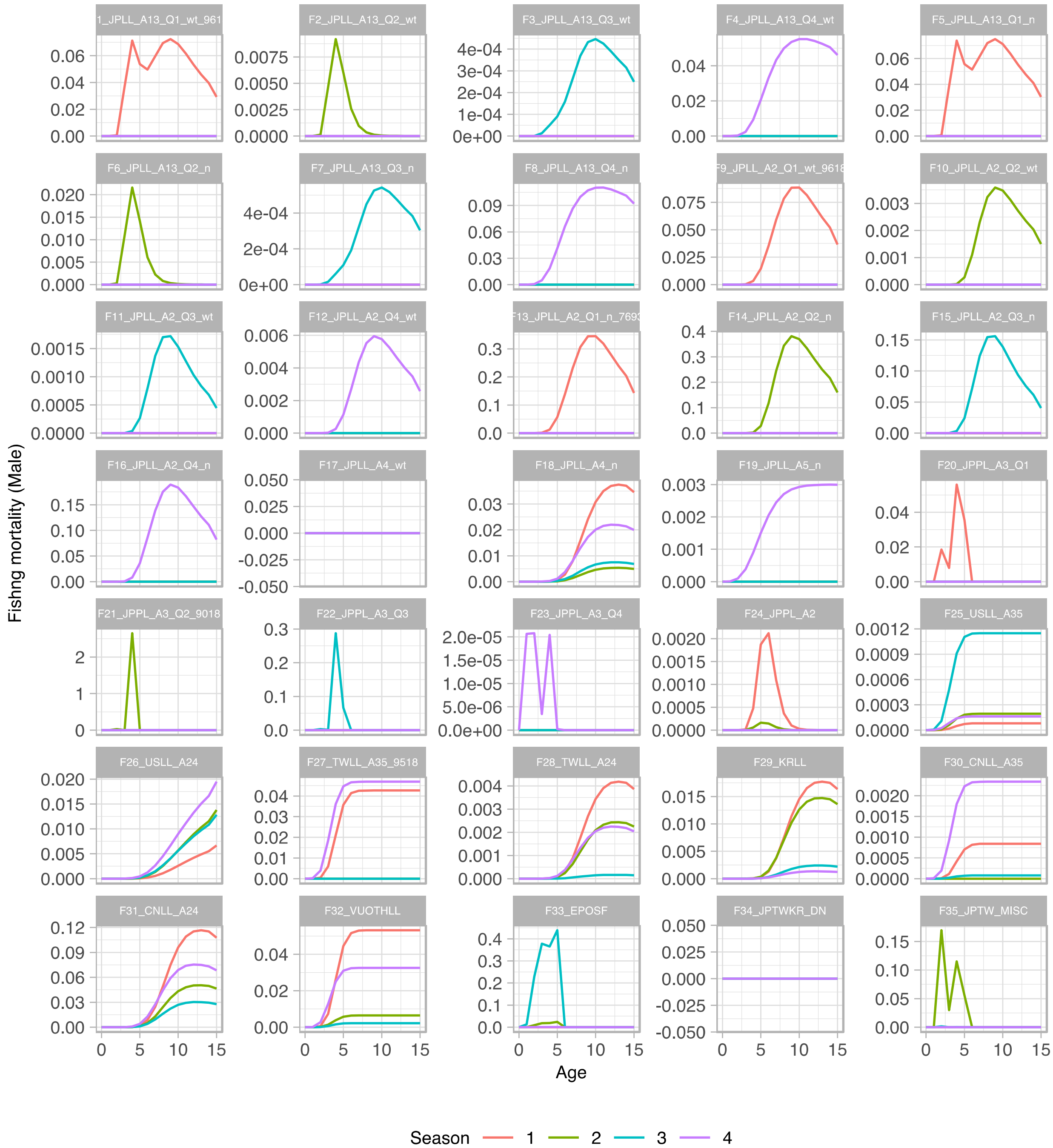

Figure 4. Male fishing mortality at age by season.

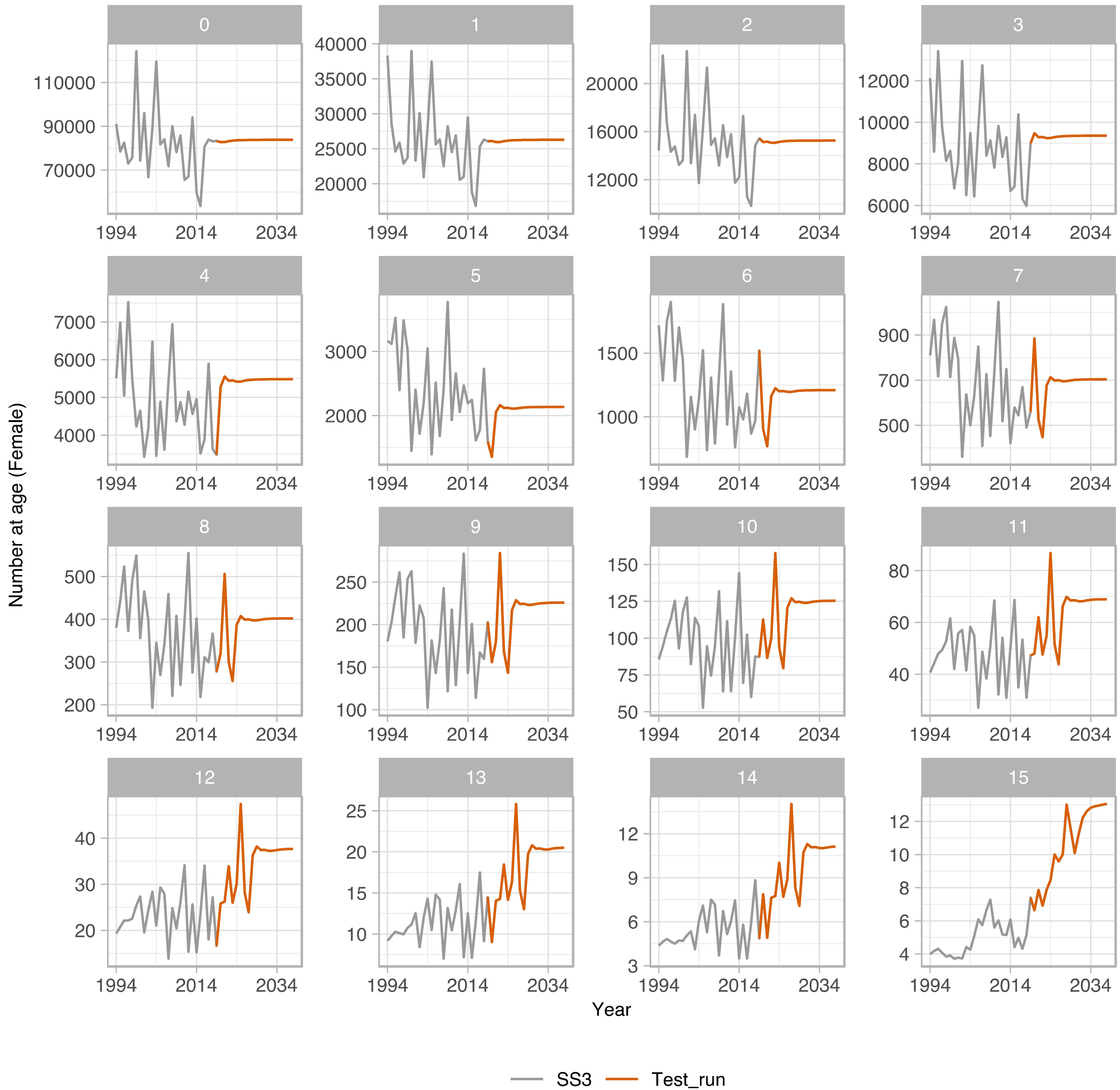

Figure 5. Estimated female number at age by deterministic future projection result using constant fishing mortality scenario (2015-2017).

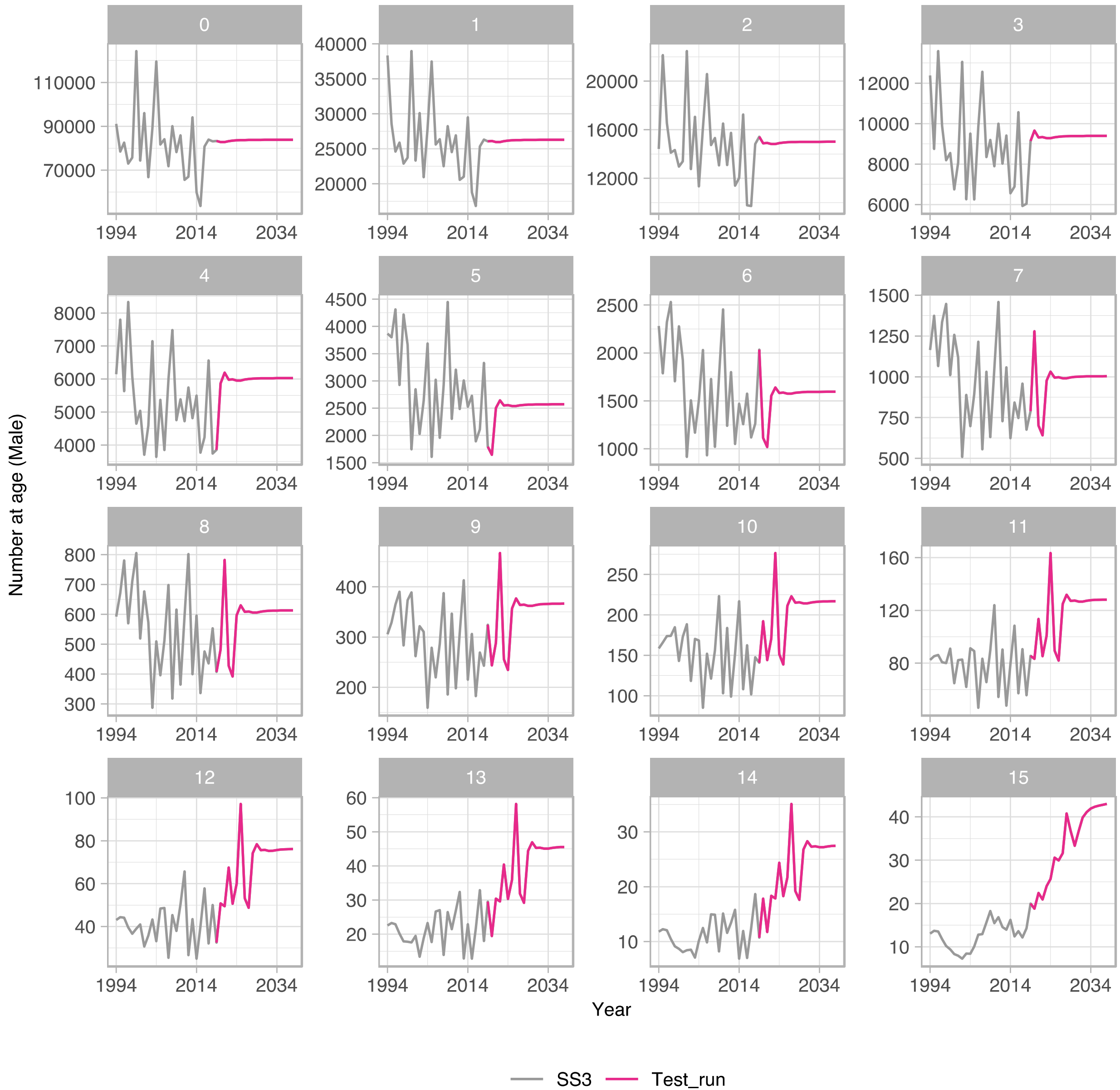

Figure 6. Estimated male number at age by deterministic future projection result using constant fishing mortality scenario (2015-2017).

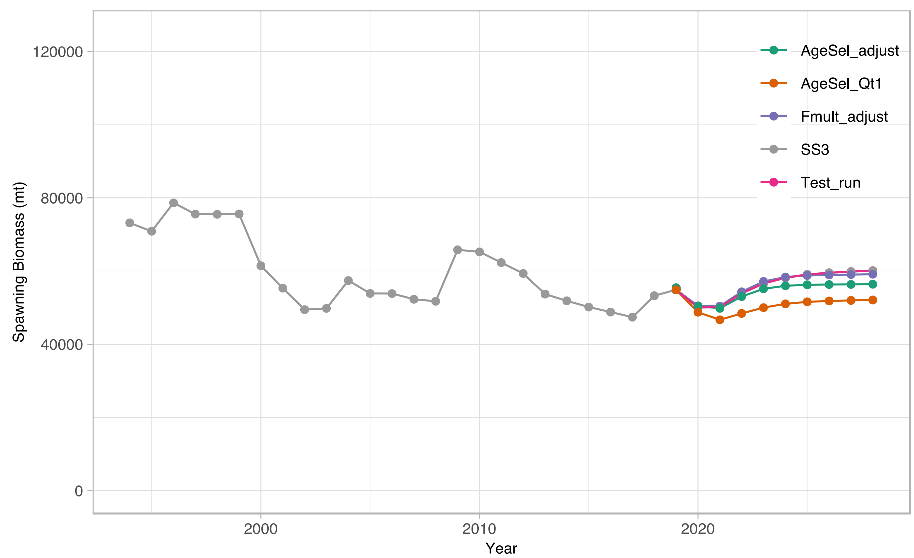

Figure 7. Estimated spawning stock biomass (2015-2017).

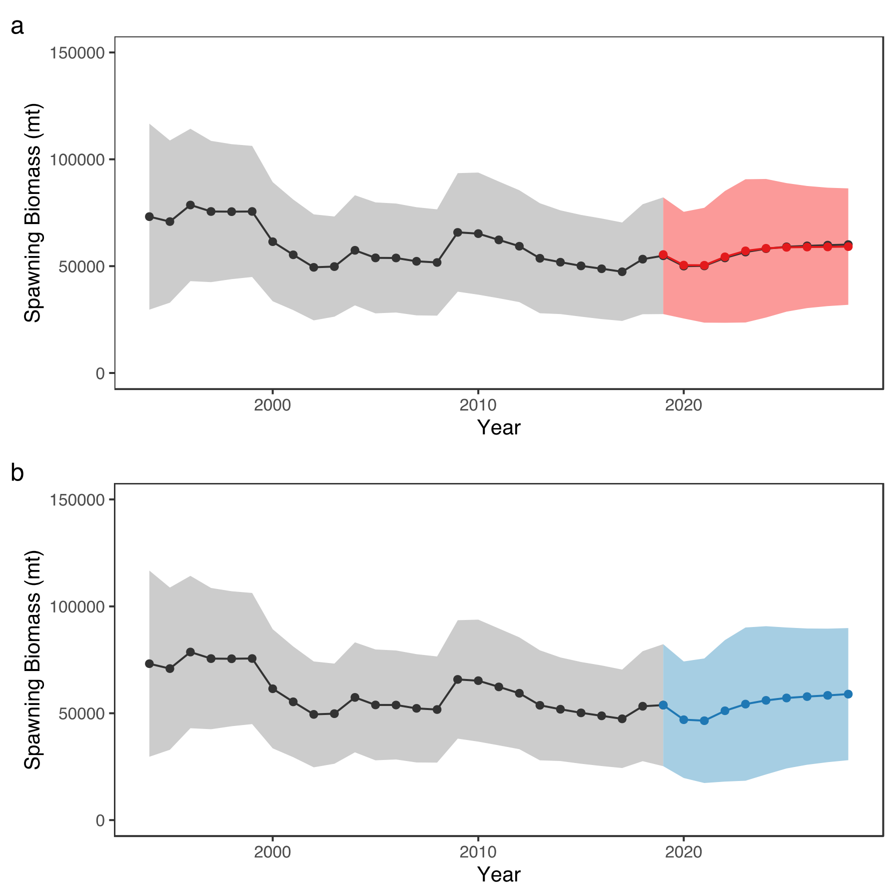

Figure 8. Future projection result using SS3 and SSfutureC++. a: Constant fishing mortality scenario (2015-2017). b: Constant catch scenario (2015-2017).