Summary of the 2024 Recommended Model Alternatives for Gulf of Alaska Pacific cod

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# Executive Summary

The explored model alternatives for the 2024 assessment of Gulf of Alaska (GOA) Pacific cod involve changes to input data. The changes implemented in the model alternatives include correcting errors in data input files, improving model consistency with other cod assessments, increasing stability of model parameters, updating important data input parameters, simplifying fishery length composition expansion methods, and improving model efficiency.

Ultimately, the model we recommend be presented for consideration at the November Groundfish Plan Team results in improvements to the model as compared to the accepted model in 2023 (model 2019.1b).

# Data

An advancement made in this year’s GOA cod assessment included re-development of the R-programming code used to query and construct data files used in the model. The historical code was refactored to facilitate implementation with contemporary software programs and open science practices, to include documentation that describes the important steps in calculations, and to integrate with current efforts to develop R-packages for data querying, specifically to integrate with the afscdata R-package. Part of this re-development involved transitioning the querying of data tables housed in both the AFSC and AK Fisheries Information Network (AKFIN) databases to only querying data from the AKFIN database.

It is normally the case that the models presented at the September Groundfish Plan Team meeting only uses data through the last full assessment. This is primarily because the alternative models explored do not significantly change sources of input data. However, because of the differences in data sources used in the re-developed R-scripts, to follow this guideline additional code would have needed to be developed in order to filter data to match exactly with what was used in the 2023 assessment. This additional code development was not undertaken for two primary reasons: (1) it did not seem like a reasonable use of assessment authors’ time to develop this code that would only be used for this single assessment cycle, and (2) because there were no surveys conducted in the GOA in 2024, thus, the model will not be updated with any population index data. For these reasons, the model alternatives presented here include updated data through the beginning of September 2024. As would be done in the November SAFE document, in the following table we highlight the data that has been added since the last full assessment:

|  |  |  |  |
| --- | --- | --- | --- |
| **Data** | **Source** | **Type** | **Years** |
| Federal and state fishery catch, by gear type (trawl, longline, and pot) | AKFIN | Metric tons | 1977 – **2024** |
| Federal and state fishery catch-at-length, by gear type | AKFIN, ADF&G | Frequency observed at length (in cm) | 1977 – **2024** |
| GOA NMFS bottom trawl survey numbers | AKFIN | Total numbers | 1990 – 2023 |
| AFSC Sablefish Longline survey Pacific cod Relative Population Numbers | AKFIN | RPN | 1990 – 2023 |
| GOA NMFS bottom trawl survey length composition | AKFIN | Number at length (in cm) | 1990 – 2023 |
| GOA NMFS bottom trawl survey conditional age-at-length | AKFIN | Proportion age at length | 1990 – 2021 |
| AFSC Sablefish Longline survey Pacific Cod length composition | AKFIN | RPN at length (in cm) | 1990 – 2023 |
| Federal fishery conditional age-at-length | AKFIN | proportion age at length | 2007 – 2022 |

# Analytic Approach

The base model used in this analysis is the accepted model from the 2023 assessment cycle (model 2019.1b). Model 19.1b is a single sex, age-based model with length-based selectivity and is optimized with the Stock Synthesis software (Methot and Wetzell 2013).

## Description of Alternative Models

### 2019.1c

There are 10 proposed changes to model input data files that culminate in model scenario 2019.1c. These changes were applied one-by-one in order to evaluate the impact of each, and are described by:

1. 2019.1c.1: when fitting a log-normal population index the log-scale standard deviation (SD) is computed as . This method had been applied in the GOA cod model for the AFSC bottom trawl survey index, but had not been applied to the AFSC longline survey index. Model 2019.1c.1 applies this method to the AFSC longline survey RPN index.
2. 2019.1c.2: in the computation of the AFSC longline survey length composition, the lengths were inadvertently set to 1 cm larger. For example, the number of fish at 50 cm became the number of fish at 51 cm. Model 2019.1c.2 assigns the correct length when computing the AFSC longline survey length composition.
3. 2019.1c.3: in the data file the month for the longline survey length composition had been set at 1 (January) when it should have been 7 (July). Model 2019.1c.3 sets the month for the AFSC longline survey length composition at 7.
4. 2019.1c.4: the fishery length composition input sample size has been set at the number of hauls sampled, with a maximum of 200. However, in the computation of fishery length composition, hauls with less than 10 observations were removed, but this filtering was not reflected in the input sample size. Model 2019.1c.4 sets the fishery length composition at the number of hauls actually used in the computation of length composition, with a maximum of 200.
5. 2019.1c.5: the plus length bin for the length composition data had been set at 116 cm, but, since 1977 less than 2% of the years had a proportion of greater than 0.01 with a plus length bin of 104 cm. Model 2019.1c.5 sets the plus length bin at 104 cm.
6. 2019.1c.6: in the data file the month for the AFSC bottom trawl survey conditional age-at-length data was set at 1 (January), when it should have been set at 7 (July). Model 2019.1c.6 sets the month for the AFSC bottom trawl survey conditional age-at-length data at 7.
7. 2019.1c.7: in the assessment, the phase for the forecast recruitment parameters was set at a value which enabled the estimation of these parameters, whereas, in the Eastern Bering Sea (EBS) cod assessment these parameters are turned off. Model 2019.1c.7 turns off the forecast recruitment parameters.
8. 2019.1c.8: a prior is added to the parameter estimating the length at the minimum age so that this parameter would not approach the lower bound of 0.
9. 2019.1c.9: the parameters describing the starting value for bottom trawl selectivity in the recent time blocks was turned off and selectivity was set at 0 up to 5 cm.
10. 2019.1c.10: a prior was added to the parameter that describes the descending limb of the bottom trawl survey selectivity in the initial time block.

### 2019.1d

Within the base model 2019.1b ageing error is applied using reader-tester data through 2017. In model 2019.1d we propose to build upon model 2019.1c and update the ageing error parameters with data through 2021. In addition, we propose to update these parameters after pooling the reader-tester data for the GOA and EBS in order to leverage the larger number of samples available within both regions. Using the a linear ageing error method within the R-package AgeingError (Punt et al. 2008) we found that there was minimal difference between the parameters estimated for each region separately, and each region combined. The estimated ageing error SD for age-1 was 0.11 regardless of how the data was pooled, and was 1.09 for the GOA, 1.14 for the EBS, and 1.13 for combined regions. Thus, in model 2019.1d we apply these updated ageing error parameters starting at age-1 (rather than age-3) with an SD of 0.11 and ending at age-10 with an SD of 1.13 with a linear relationship between.

Because bias was discovered in the age reading for cod prior to 2007 (Barbeaux ###) model 2019.1b estimates two parameters to apply bias in the ageing error for any age data fit prior to 2007 (a parameter for the bias starting at age-3 and the bias for the final age in the model, age-10, with a linear trend between these ages). In 2018, a set of specimen data (n = 2,056) that was originally aged in 2004 was re-read by age readers in the AFSC Age and Growth Program. Using this data within the AgeingError R-package we estimated the bias in the pre-2007 data (Figure 1). In model 2019.1d, rather than estimate bias, we set the bias parameters based on the results from the AgeingError model fit, where the bias was 0.24 for age-1, and 2 for age-10, with a linear relationship defined in the model between these two ages.

### 2019.1e

As was noted in the 2023 assessment, fishery length composition (specifically for the pot fleet) has become increasingly variable. Within model 2019.1e we propose changes to the methods used to compute fishery length composition that aid in reducing this variability.

In the expansion of fishery length frequency observations to annual fishery length composition for each gear type fit in the cod assessment model (trawl, longline, and pot fisheries) hauls have been removed that sampled less than 10 fish for length frequency within the haul. Prior to around 2015, this represented a small proportion of hauls, particularly for the Longline and Trawl fleets (Table 1). However, since 2015 the numbers of hauls that sampled less than 10 fish per haul has increased. For example, since 2020 around 70% of the hauls sampled in the Trawl fleet had less than 10 length frequencies observed per haul.

Length frequencies are also collected within the fisheries managed by the Alaska Department of Fish and Game (ADF&G) and have been integrated within the GOA cod assessment. The use of ADF&G length frequency data occurs when there is federal data missing at a trimester-area-gear level.

In model 2019.1e we use model 2019.1d and include two changes to how fishery length frequency data is handled. First, we eliminate the filter that removes hauls that sampled less than 10 lengths and use all haul data available. Second, rather than ‘fill-in’ missing federal length frequency data with ADF&G data we merge the ADF&G data with the federal data so that all length frequency data from both sources can be used in the expansion of length composition data fit in the GOA cod assessment. In general, these two changes help to smooth out much of the variability in the fishery length composition data (2020 Pot fishery length composition shown in Figure 2 as an example).

Two additional models were considered as a subset of model 2019.1e to evaluate model performance and sensitivity to the bin size within the length composition and conditional age-at-length data. The first additional model, 2019.1e.2cm evaluates using 2 cm bins, and the second, 2019.1e.5cm, evaluates using 5 cm bins. Using recent bottom trawl survey length compositions as an example, increasing the bin size serves to smooth the length composition while retaining important signal within the data (Figure 3).

# Results

## Model 2019.1c

The majority of the model changes made within model 2019.1c resulted in minor changes to assessment estimates (Table 3). Only three model changes resulted in an average percent difference in estimates of spawning biomass that was greater than 1%: 2019.1c.4 in which the input sample size for fishery length composition data was set at the number of hauls actually used to compute length composition, 2019.1c.5 in which the plus length group was set at 104 cm, and 2019.1c.6 in which the month for bottom trawl survey conditional age-at-length was changed from 1 (January) to 7 (July). The largest of these was from model 2019.1c.6, which resulted in a 14% decrease in spawning biomass estimates on average. Combining all of these changes within model 2019.1c resulted in a decrease in the estimated spawning biomass across the time series of the model (Figure 4).

## Model 2019.1c – removing AFSC longline catchability environmental link

For comparison with the current model configuration, in which the AFSC longline survey catchability is estimated with an environmental link to the CFSR index, we constructed model variant 2019.1c, in which the environmental link was removed. To perform this comparison, we did a retrospective analysis, in which the AIC value from model 2019.1b was compared to the AIC value from model 2019.1c for the last 10 years. For each of the last 10 years the AIC value from model 2019.1b was smaller than 2019.1c (Table 2), indicating that even with the addition of the environmental link parameter in model 2019.1b, model 2019.1b is continually preferred over 2019.1c. Further, Mohn’s ρ from each model was nearly the same, -0.0727 from model 2019.1b and -0.0722 from model 2019.1c. Due to the continued and sustained improvement resulting from the environmental link to the AFSC longline survey catchability in model 2019.1b, we recommend that the environmental link to AFSC longline survey catchability be continued in future assessments.

## Model 2019.1d – reevaluation of the AFSC longline catchability environmental link

To reevaluate the environmental link to the AFSC longline survey catchability parameter we performed an analysis in which each combination of month-size range in the CFSR data was sequentially used in model 2019.1b. Table 3 shows the difference in AIC value between the base model (2019.1b) and the model with each CFSR index by month and size range. While the current CFSR index used is still an improvement over a model with no environmental link (as discussed in the previous section), the CFSR index that resulted in the smallest AIC value was for the 40-60 cm size range with March temperatures (Table 3). Currently, the 0-20 cm size range for June temperatures is used (which is why the AIC difference in Table 3 is 0 in this case). We now denote model variant 2019.1d as the model that utilized the CFSR index that results in the smallest AIC value. Compared to model 2019.1b, model 2019.1d resulted in an overall decrease in the total likelihood, which is primarily driven by an improved fit to the AFSC longline survey index (Table 4 and Figure 4), particularly in recent years (e.g., 2019). For further comparison with the current base model configuration we performed a retrospective analysis in which models 2019.1b and 2019.1d are compared. Since 2019 the total likelihood for model 2019.1d has been smaller than 2019.1b, however, prior to 2018 the total likelihood from model 2019.1b was smaller. Mohn’s ρ from model 2019.1b was -0.0727 and from model 2019.1d was -0.0579, indicating that the new CFSR index improves retrospective performance. An increase in spawning biomass was estimated by model 2019.1d in comparison to model 2019.1b as well as 2019.1a (shown in Figure 5 for reference); in 2022 this resulted in an 11% increase in spawning biomass from model 2019.1d compared to model 2019.1a. Due to the improvement in model fit to the AFSC longline survey index, particularly for the recent surveys, we recommend that model 2019.1d be considered as an alternative model to be presented in the full assessment for 2023.

# Literature Cited

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# Tables

Table 1. Percent of hauls within fishery length frequency data that sampled less than 10 lengths per haul.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | | Longline | Pot | Trawl |
| 1991-2012 | 2% | | 4% | 3% |
| 2013 | 12% | | 12% | 2% |
| 2014 | 6% | | 14% | 5% |
| 2015 | 5% | | 8% | 4% |
| 2016 | 13% | | 10% | 4% |
| 2017 | 12% | | 12% | 20% |
| 2018 | 23% | | 6% | 6% |
| 2019 | 22% | | 10% | 6% |
| 2020 | 60% | | -- | 79% |
| 2021 | 20% | | 14% | 72% |
| 2022 | 6% | | 30% | 76% |
| 2023 | 34% | | 36% | 68% |

Table 2. Percent of ADF&G length frequency data used to compute fishery length compositions in the GOA cod assessment.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Longline | Pot | Trawl |
| 1997-2016 | 35% | 19% | 38% |
| 2017 | 33% | 0% | -- |
| 2018 | 40% | 33% | -- |
| 2019 | 40% | 50% | -- |
| 2020 | 100% | 100% | -- |
| 2021 | 67% | 67% | -- |
| 2022 | 60% | 0% | -- |
| 2023 | 50% | 100% | -- |

Table 3. Average percent difference in estimated spawning biomass (SSB) from models considered within model 2019.1c compared to the base model 2019.1b.

|  |  |
| --- | --- |
| Model | % difference in SSB |
| 2019.1c | -14.67% |
| 2019.1c.1 | 0.02% |
| 2019.1c.2 | -0.33% |
| 2019.1c.3 | 0.82% |
| 2019.1c.4 | 3.95% |
| 2019.1c.5 | -1.17% |
| 2019.1c.6 | -14.65% |
| 2019.1c.7 | -0.18% |
| 2019.1c.8 | 0.00% |
| 2019.1c.9 | -0.28% |
| 2019.1c.10 | 0.01% |

Table 4. Likelihood components from model 2019.1b and 2019.1d. The ‘Difference’ column is highlighted in green when 2019.1d has a smaller likelihood value than 2019.1b, red when the likelihood value is greater.

|  |  |  |  |
| --- | --- | --- | --- |
| Likelihood | 2019.1b | 2019.1d | Difference |
| TOTAL | 2780.1 | 2772.0 | -8.1 |
| Catch | 6.65E-13 | 4.08E-13 | 0.0 |
| Survey | -12.8 | -19.2 | -6.4 |
| Srv | -9.6 | -9.1 | 0.6 |
| LLSrv | -3.1 | -10.2 | -7.0 |
| Length\_comp | 1712.8 | 1711.9 | -0.9 |
| Age\_comp | 1062.9 | 1062.8 | -0.2 |
| Recruitment | 4.4 | 4.1 | -0.3 |
| InitEQ\_Regime | 2.5 | 2.2 | -0.3 |
| Forecast\_Recruitment | 2.6 | 2.6 | -0.1 |
| Parm\_priors | 1.1 | 1.1 | 0.0 |

Table 5. Retrospective total likelihood for model 2019.1b and 2019.1d. The ‘Difference’ column is highlighted in green when 2019.1d has a smaller likelihood value than 2019.1b, red when the likelihood value is greater.

|  |  |  |  |
| --- | --- | --- | --- |
| Retro Year | 2019.1b | 2019.1d | Difference |
| 2022 | 2780.1 | 2772.0 | -8.1 |
| 2021 | 2669.7 | 2662.6 | -7.1 |
| 2020 | 2503.0 | 2496.7 | -6.3 |
| 2019 | 2400.7 | 2394.1 | -6.7 |
| 2018 | 2251.6 | 2258.0 | 6.4 |
| 2017 | 2181.8 | 2189.0 | 7.2 |
| 2016 | 2046.8 | 2055.9 | 9.1 |
| 2015 | 1903.3 | 1912.8 | 9.5 |
| 2014 | 1769.5 | 1779.1 | 9.6 |
| 2013 | 1648.3 | 1658.0 | 9.6 |

# Figures

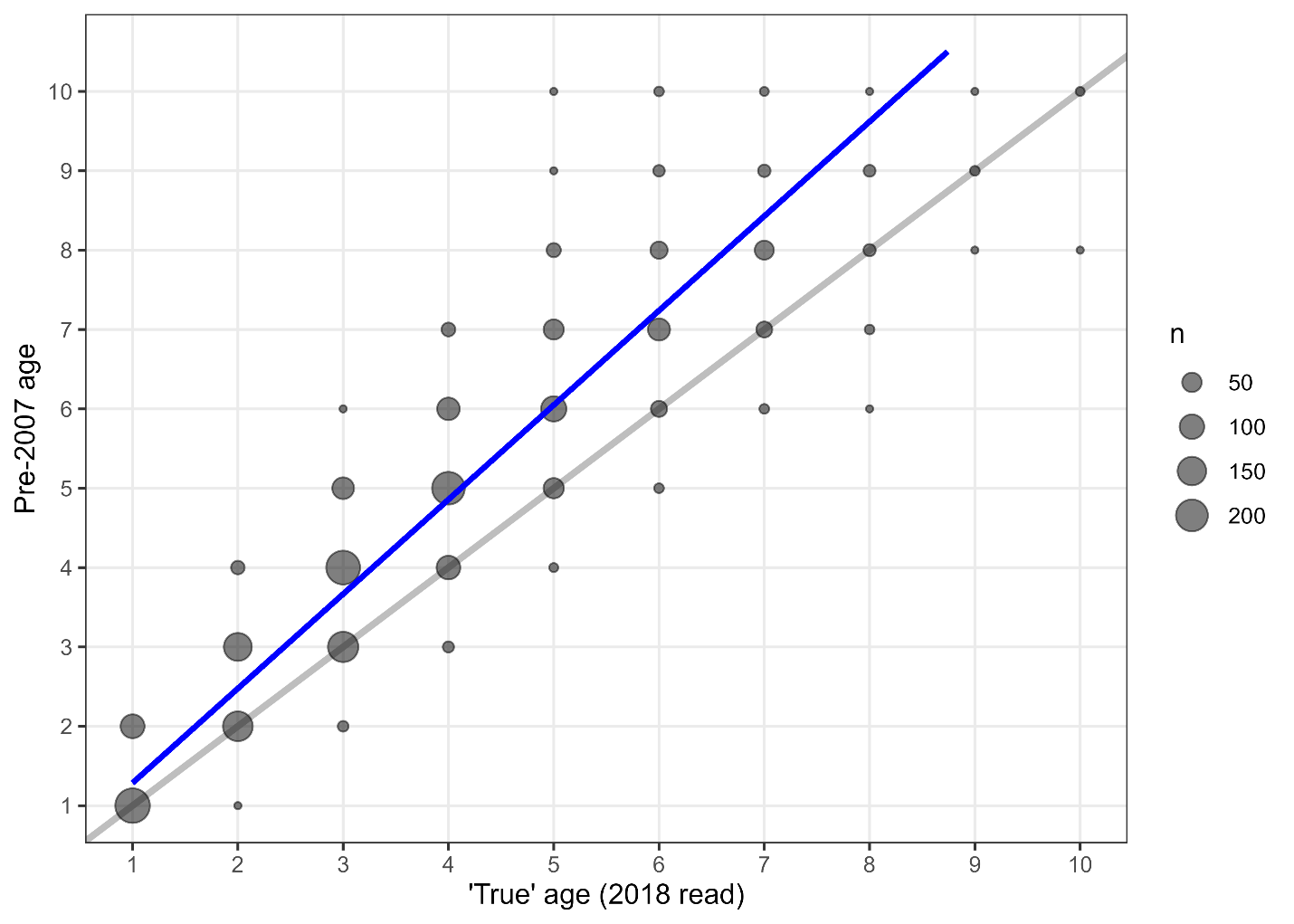


Figure 1. AgeingError R-package fit (blue line) to bias in ageing (grey line is 1-1 and shown for reference).

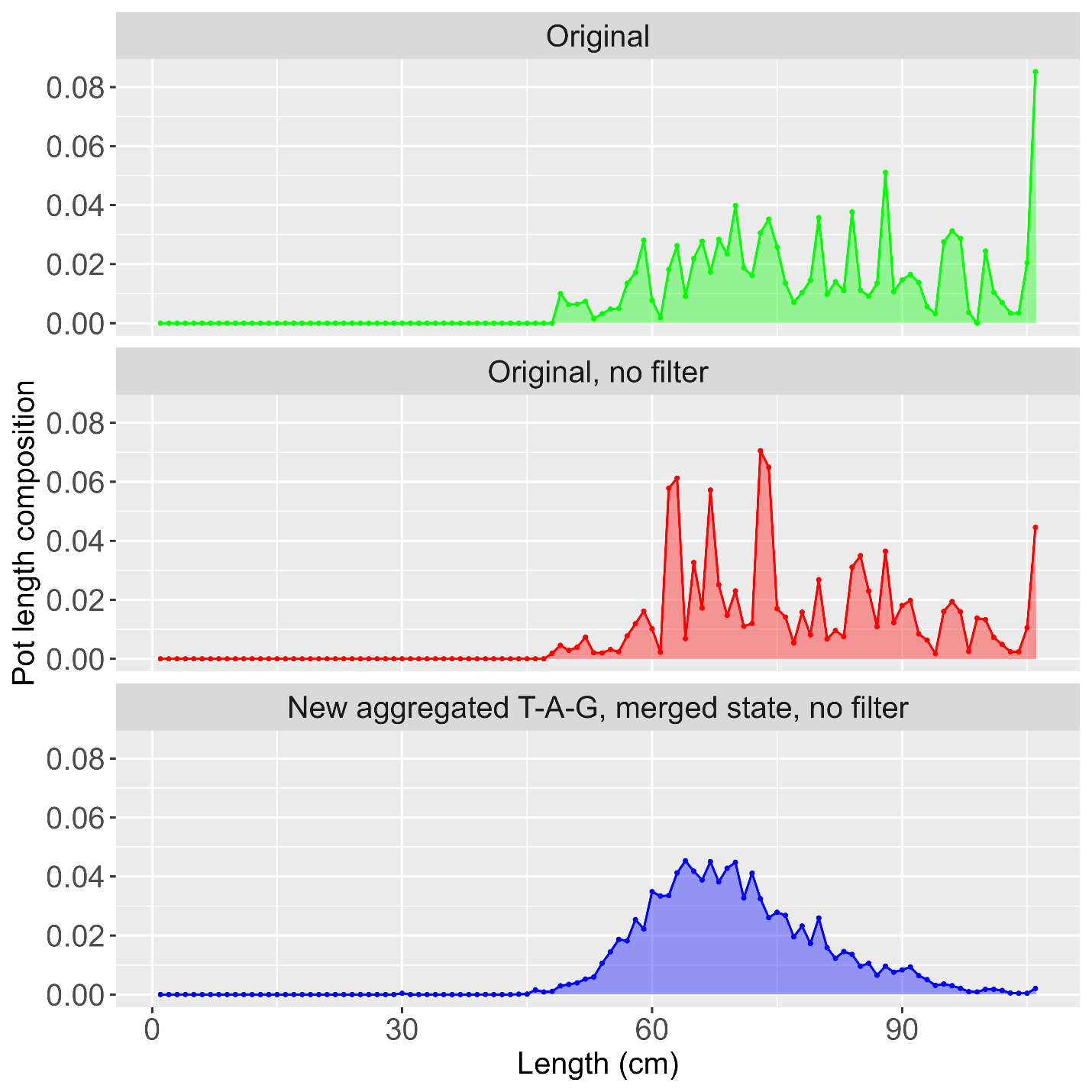


Figure 2. 2020 Pot fishery length composition using the original method for filtering and using ADF&G length frequency data (top panel), remove the greater than 10 lengths per haul filter (middle panel), and merging ADF&G length frequency data with federal data (bottom panel).



Figure 3. Recent bottom trawl survey length composition computed for 1cm (lcomp\_new shown in blue), 2 cm (lcomp\_new\_bin2 shown in red), and 5cm (lcomp\_new-bin5 shown in green) length bins.

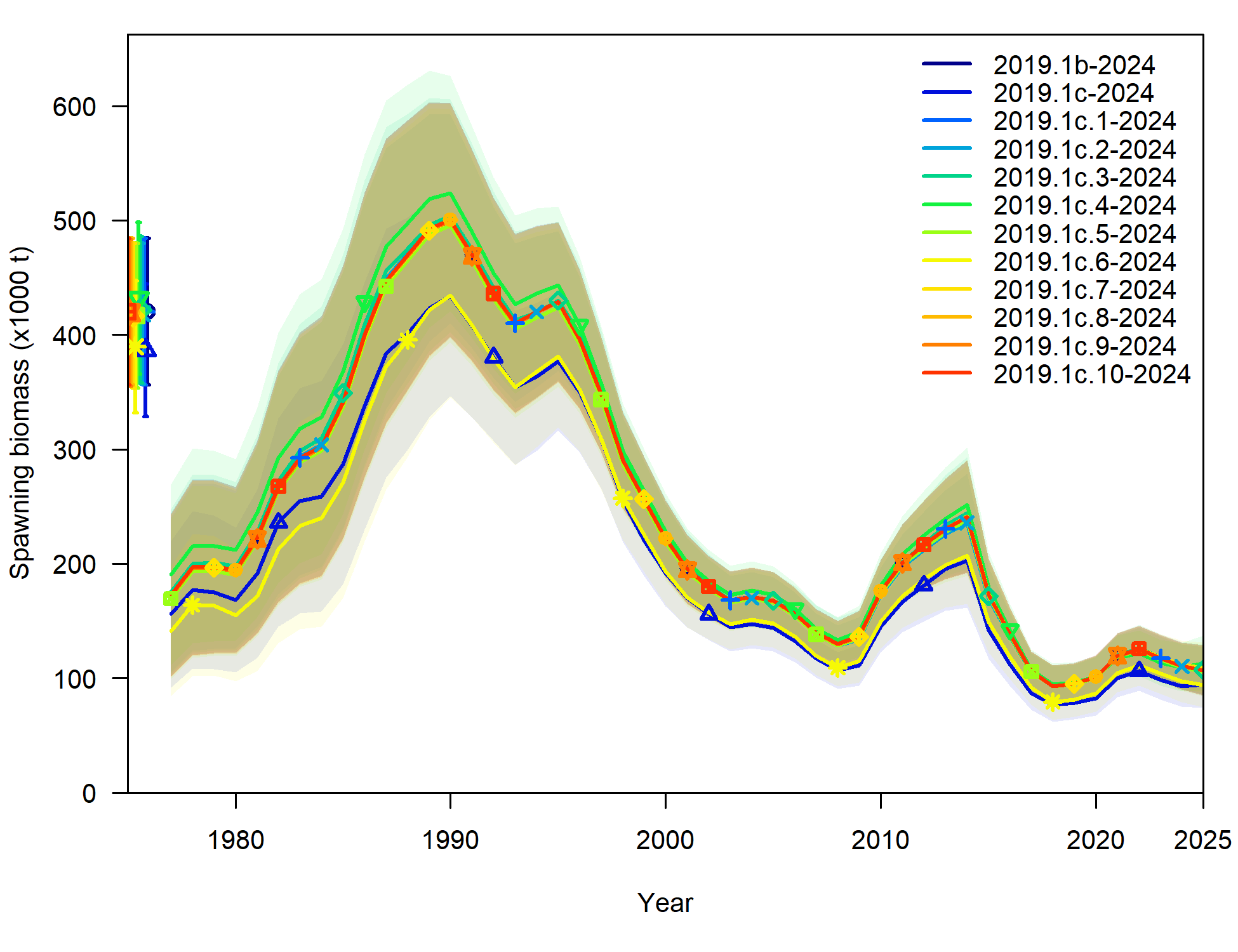


Figure 4. Estimated spawning biomass for the models considered in 2019.1c as compared to the 2023 assessment (2019.1b-2023) and the 2023 assessment with updated data (2019.1b-2024).

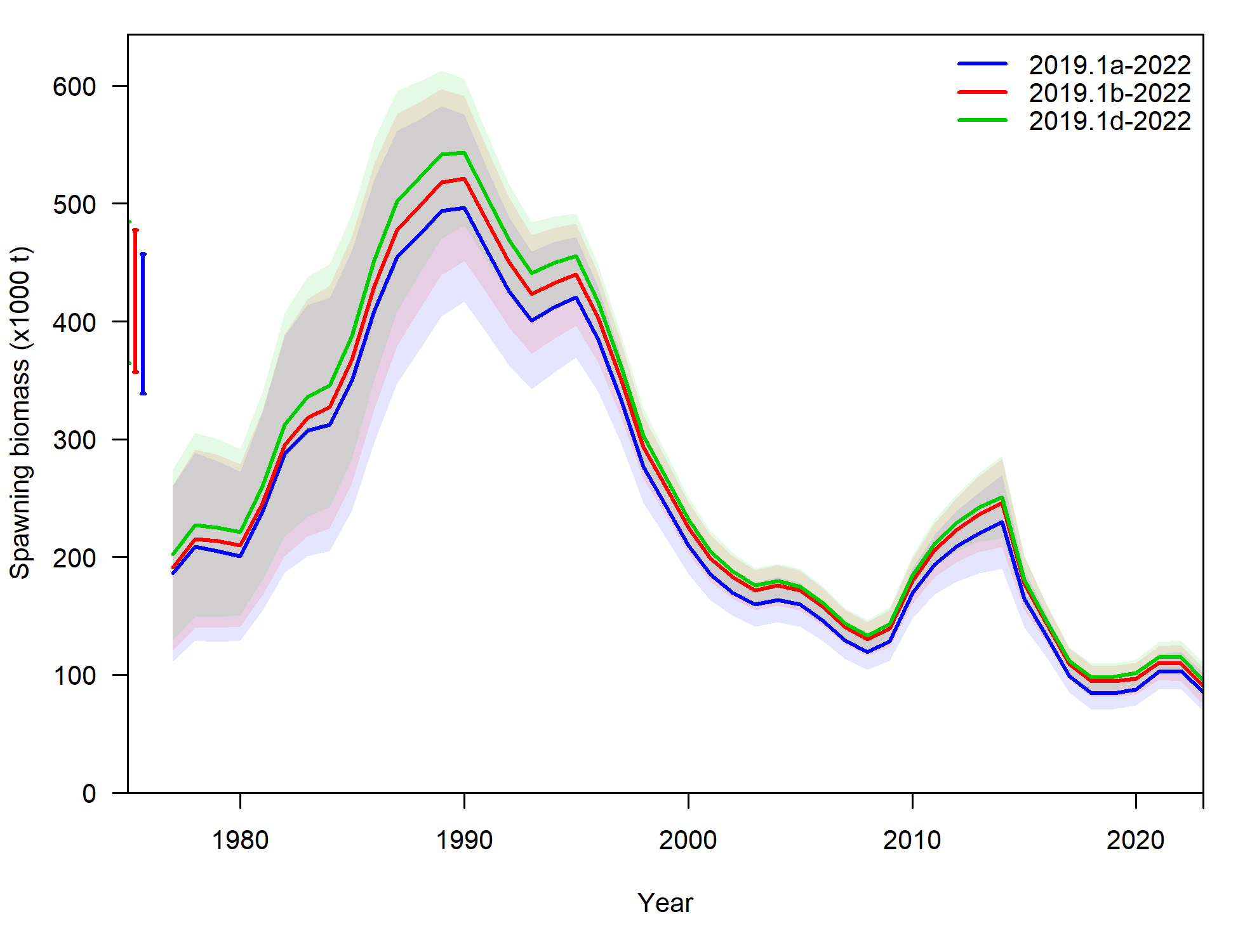


Figure 5. Estimated spawning biomass from models 2019.1a, 2019.1b, and 2019.1d.