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Development of a preliminary model for the 2020 north Pacific albacore tuna stock assessment[1]

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ABSTRACT

The objective of this working paper is to describe the development of the preliminary model for the 2020 assessment of NPALB. We developed the model in a stepwise fashion by incorporating the data submitted by ALBWG members, previously agreed upon model structure and biological parameters, and the best features of the previously suggested improvements. The model is expected to have a main model period of 1994 – 2018. Three types of data were used in this study: fishery-specific catches, size composition, and abundance indices. The geographic area and spatial stratification of this study followed that of the 2017 assessment (Pacific Ocean north of the equator (0°) to 55°N and from 120°E to 100°W). Thirty-five (35) fisheries were defined for this study on the basis of gear, fishing area, season, and unit of catch (numbers or weight), and all catch and effort data were allocated to these fisheries. Catch was reported and compiled in weight (metric tons) or 1000s of fish. Catch for most fisheries were almost identical to the 2017 assessment but there were non-negligible differences in catch for some fisheries. The abundance index from the Japanese longline fishery in Area 2 and Quarter 1 (F9; 1996 - 2018) was used as the index of adult albacore abundance. Quarterly length composition data from 1994 through 2018 were used in this assessment. Length data were available for 22 of the 35 fisheries and were compiled into 2-cm size bins. Similar to previous assessments, we used the Stock Synthesis (SS) modeling platform in this study. The biological parameters used in this study were the same as for the 2017 assessment. Similarly, selectivity curves were largely based on the selectivity curves in the 2017 assessment but this study investigated several improvements. The major steps in the development of the preliminary model were as follows:

1) Update data from 2017 to 2020, using the 2020 fishery definitions but otherwise similar to the 2017 assessment (e.g., mirrored selectivities for fisheries that were combined in the 2017 assessment, 2017 size data weightings).
2) Selectivity of fisheries that were split into seasonal fisheries (F10-F12; F14-16; F20-F21; and F22-F23) were allowed independent selectivities (using 2017 size data weightings).
3) Japan pole-and-line fleets in Q2 (F21) and Q3 (F22), which are the largest source of removals, are allowed to have annually varying age selectivity (if data are available).
4) Used alternative weighting scheme such that the weighting per sample was relatively equal between fisheries. Sample size multiplier of 0.1626 for all fisheries.
5) Evaluate conflicts between fishery-specific size composition data and the primary adult index; and evaluate the relative influence of the fishery-specific size composition data on the estimated population scale. Size composition data for specific fisheries were down-weighted or additional model processes incorporated, where appropriate.

Overall, we believe that the preliminary model is a reasonable starting point for the ALBWG to develop the 2020 assessment of NPALB. The preliminary model was found to have a reasonably well observed production function, which means that the catch time series and estimated productivity can explain much of the changes in the observed population, and adds confidence that the estimated population scale is approximately right. In addition, the minima of the R0 profile for the adult abundance index is approximately in the right region as the maximum likelihood estimate of the R0 of the model.

INTRODUCTION

The Albacore Working Group (ALBWG) of the International Scientific Committee for Tuna and Tuna-like species in the North Pacific Ocean (ISC) is responsible for conducting stock assessments of North Pacific albacore tuna (NPALB). The previous two assessments were conducted in 2014 and 2017 (ALBWG 2014, 2017). In preparation for the upcoming stock assessment of NPALB scheduled for 2020, Teo et al. (2019) re-examined the 2017 base case model and identified several potential improvements.

Based on that discussion, the ALBWG recommended that a similar base case scenario as in the 2017 assessment be used for the 2020 assessment, albeit with several options for possible improvements (ALBWG 2019). The ALBWG agreed to develop two candidate models (Models A and B) for evaluation as the base case model for the 2020 stock assessment, with priority to be given to Model A.

Model A will be similar to the base case model in the 2017 assessment, with a main model period of 1994 – 2018. However, several improvements to the model are possible, including time annually varying age selectivity of the surface fleets, M and *h* priors, and the inclusion of juvenile/subadult indices from Japan longline fisheries in Areas 1 and 3.

Model B will be largely identical to Model A during the 1994 - 2018 period. However, the start year of Model B will be from 1966. Therefore, catch and size composition data from 1966 to 1993 will be included in Model B. In addition, an adult index from Japan longline fisheries in Area 2 will be included for 1976 – 1993.

The objective of this paper is to describe the development of Model A to act as the preliminary model for the 2020 assessment of NPALB. We developed the model in a stepwise fashion by incorporating the data submitted by ALBWG members, previously agreed upon model structure and biological parameters, and the best features of the suggested improvements by Teo et al. (2019).

MATERIALS AND METHODS

Spatial and temporal stratification

Three types of data were used in this study: fishery-specific catches, size composition, and abundance indices. These data were originally compiled from 1966 through 2018. However, with the focus of this study on Model A, all models in this study have a start year of 1994, which was similar to the base case model for the 2017 assessment (start year of 1993). The data for Model B (1966 – 2018) have also been compiled but are not discussed further in this study. In addition, the ALBWG also compiled conditional age-at-length data, which were used in the 2014 assessment but were not used here nor in the 2017 assessment.

The geographic area and spatial stratification of this study followed that of the 2017 assessment (Pacific Ocean north of the equator (0°) to 55°N and from 120°E to 100°W) (Fig. 1). Models in this study were not spatially explicit but fisheries were defined using multiple criteria, including fishing area, and therefore implicitly included spatial inferences (Table 1). Analyses of fishing operations and size composition data from Japanese and US longline vessels in the north Pacific showed that there were five areas with relatively consistent size distributions of albacore (ALBWG 2016; Ochi et al. 2016; Teo 2016), which were used to define fisheries in the 2017 assessment (ALBWG 2017) (Fig. 2).

Fishery definitions

Thirty-five (35) fisheries were defined for this study on the basis of gear, fishing area, season, and unit of catch (numbers or weight), and all catch and effort data were allocated to these fisheries (Table 1). This study had a larger number of fisheries than were defined in the 2017 assessment (29) because the size compositions of the Japanese longline fisheries in Area 2 and Japanese pole-and-line fisheries in Area 3 were substantially better fit as seasonal fisheries (Table 1). The aim was to define relatively homogeneous fisheries with greater differences in selectivity and catchability between fisheries than temporal changes in these parameters within fisheries. These fisheries consisted primarily of 23 longline fisheries from Japan (F1 – F19), USA (F25 & F26), Chinese-Taipei (F27 & F28), Korea (F29), China (F30 & F31), and Vanuatu and Others (F32) (Table 1). There were also five pole-and-line fisheries from Japan (F20 – F24), and the surface gears (primarily troll and pole-and-line) from Canada, Mexico, and the USA, which were combined into a single surface gear fishery (F33). In addition, drift net catches from Japan, Korea, and Chinese-Taipei were combined into a single fishery (F34), which was important in the past but less so during the modeling period; and catch from all other miscellaneous gears (e.g., purse-seine) from Japan and Chinese-Taipei were combined into a single miscellaneous fishery (F35). The approximate fishing area of each fishery can be deduced from Table 1 and Figure 1.

Catch

Estimates of total catch in each fishery were compiled by calendar quarter for 1966 – 2018 but only catch during 1994 – 2018 were used for this study. Catch was reported and compiled in original units consisting of weight (metric tons) or 1000s of fish (Table 1). Catch for most fisheries were almost identical to the 2017 assessment but there were non-negligible differences in catch for F30, F31, and F32 (Fig. 2). Note that F17 and F34 have zero catch during 1994 – 2018 but the fisheries were maintained for the convenience of developing a model for 1966 – 2018.

Abundance indices

The ALBWG reviewed the available abundance indices during the data preparatory meeting (ALBWG 2019), including Japanese longline (Fujioka et al. 2019), Japanese pole-and-line (Matsubara et al. 2019), and Taiwanese longline (Chen and Cheng 2019) fisheries. Based on this review, the ALBWG recommended the use of the abundance index from the Japanese longline fishery in Area 2 and Quarter 1 (F9; 1996 - 2018) as the index of adult albacore abundance. In addition, the ALBWG also recommended testing the use of the abundance index from the Japanese longline fishery in Area 1 and 3, during Quarter 1 (F1; 1996 - 2018) as an index of juvenile/subadult albacore abundance. The Japanese pole-and-line and Taiwanese longline indices were recommended by the ALBWG for sensitivity runs (ALBWG 2019).

The F9 index is essentially the same adult albacore index used for the 2017 assessment, albeit with three additional years of data. A Bayesian zero-inflated negative binomial generalized linear mixed effects model (Bayesian ZINB GLMM) was used to standardize the catch and effort data. The ALBWG observed that the Pearson residuals in preliminary indices were biased in 1994 and 1995, likely due to changes in targeting and species compositions, and therefore decided to start the index in 1996. Further details on the data and standardization model can be found in Fujioka et al. (Fujioka et al. 2019).

The F1 index was not available for the 2017 assessment but preliminary examination of model fits and lagged correlations with the F9 index suggested that the F1 index was consistent with the F9 index and may be useful as an index of juvenile/subadult albacore abundance (ALBWG 2019; Fujioka et al. 2019; Teo et al. 2019).

Annual values and coefficients of variation (CVs) for F1 and F9 indices are shown in Figure 3. Nominal months were assigned to each index based on the quarter in which the majority of catch was recorded. The relative weighting of the indices was controlled by adjusting the input CVs. Based on the fit of indices to a loess spline, additional mean CVs of 0.165 and 0.100 were added to the F1 and F9 indices to result in mean CVs of 0.281 and 0.200, respectively.

Size composition

Quarterly length composition data from 1994 through 2018 were used in this assessment. Length data were available for 22 of the 35 fisheries (Table 1) and were compiled into 2-cm size bins, ranging from 26 to 142 cm FL, where the labels are the lower boundary of each bin (Fig. 4 – 22).

The length frequency observations were the estimated catch-at-size (i.e., size compositions were raised to the catch) for 19 of the fisheries with size composition data and these size composition data were fitted in the base case model (Table 1). However, the size composition data from three of the fisheries (F30 – F32) could not be raised to the catch and were not fitted. Instead, it was assumed that the selectivity of these fisheries were the same as other longline fisheries with similar fishing operations and fishing area.

The effective sample size for size composition data is usually substantially lower than the actual number of fish measured because the variance within each set or trip is substantially lower than the variance within a population (Pennington et al. 2002). However, the only common unit for the sample size from albacore fisheries is the number of fish measured. Based on an analysis of the EPO surface fishery (F33), we assumed that 100 fish were measured per trip. Therefore, the input sample size for all fisheries were calculated by dividing the number of fish sampled by 100. Size composition records with sample sizes of <1 were considered unrepresentative and removed.

Furthermore, a decision has to be made on the relative weights of the size composition data between fisheries. In the 2017 assessment, the input sample sizes for fisheries with average input sample sizes >7 (i.e., all except for USLL_A35 and USLL_A24) were further rescaled by a multiplier so that the average input sample size for each fishery was approximately the same as for the US longline fisheries (~7). However, that resulted in the relatively low weighting per sample for well-sampled fisheries as compared with less sampled fisheries. For example, weighting per unit sample for F25_USLL_A35 would be approximately 146x higher than for the best-sampled fishery, F1_JPLL_A13_Q1. During the model development of the 2017 assessment model, the size composition data for some fisheries were further down-weighted by using lambda factors in order to improve the fit to the abundance index. In this study, we developed an alternative weighting scheme such that the weighting per sample was relatively equal between fleets. The input sample sizes of the best-sampled fishery (F1) were rescaled by a multiplier (0.1626) such that the average input sample size for the fishery was ~30. The same multiplier was then used for all fisheries.

Biological parameters

The biological parameters used in this study were the same as for the 2017 assessment.

Fixed sex-specific growth curves from Xu et al (2014), and non sex-specific seasonal weight-at-length relationships study from Watanabe et al. (2006) were used in this study, which were also used for the 2014 and 2017 assessments.

Age and sex-specific natural mortality parameters were from Teo (2017). Meta-analytical methods on a range of empirical relationships between natural mortality (M) and life history parameters (Hamel 2015; Then et al. 2015; Kinney and Teo 2016; Teo 2017) identified an M of 0.38 and 0.49 y^{-1} for adult male and female albacore tuna, respectively. The M of juvenile north Pacific albacore tuna was assumed to follow a Lorenzen (1996) relationship between size and M for age-0 to age-2, with no difference between the sexes until age-3+. Upon reaching age-3, the M for male albacore was assumed to be 0.38 y^{-1} and the M for female albacore was assumed to be higher, reaching 0.49 y^{-1}, which may reflect the cost of reproduction. Although not used for the 2017 assessment, the lognormal priors for the M of adult male and female albacore tuna had means of -0.938 and -0.726, respectively, and a σ of 0.457 for both sexes.

Steepness of the stock-recruitment relationship (h) was defined as the fraction of recruitment from a virgin population (R_0) when the spawning stock biomass is 20% of its unfished level (SSB_0). Two independent estimates of steepness for north Pacific albacore (Brodziak et al. 2011; Iwata et al. 2011), based on the life history approach of Mangel et al. (2010), reported values of h ranging from 0.84 to 0.95, and values of σ_h ranging from 0.01 to 0.04. Therefore, the ALBWG assumed a fixed steepness value of 0.9 for past assessments. In this study, we also assume a fixed steepness value of 0.9 for most models but also assume a prior for steepness of $N(\mu=0.9, \sigma=0.05)$ for alternative model runs.

Recruitment variability (σ_R) was fixed to approximate the expected variability of 0.4, based on an early run of the model. Bias adjustment was also used to account for the reduction in information content from the data on recruitment deviations during different periods in the model time frame. This adjustment mostly affects the estimation of uncertainty and not the population trajectory. However, both recruitment variability and bias adjustment parameters are expected to be changed as model development continues.

Modeling platform

Similar to previous assessments, we used the Stock Synthesis (SS) modeling platform in this study. There was a major change in the version of SS used in the 2017 assessment (v3.24) to this study (v3.30). Teo (2019) found that the both versions resulted in nearly identical results for the base case model of the 2017 assessment. Therefore, this study only focused on the latest version of SS available during the study (v3.30.14.08).

Fishery selectivity

Selectivity curves were largely based on the selectivity curves in the 2017 assessment (ALBWG 2017). Although the models in this study were sex-specific, the selectivity curves were not sex-specific due to a lack of sex-specific composition data. Selectivity curves were fishery-specific and assumed to be a function of only size for all but five fisheries (F20-23 and F33). The size composition data of these five fisheries exhibited very strong modes corresponding to juvenile age classes and could not be adequately fit using only size selectivity curves. Therefore, the selectivity curves of these fisheries were assumed to be a product of size and age, which improved model fits.

Although the selectivity curves in this study were based on the 2017 assessment, we also investigated the effect of having annually varying age selectivities for F21 and F22. These two fisheries had highly variable age modes, which may reflect the changing availability of age classes to the fishing area. Using annually varying selectivities appeared to substantially improve the model fits to the apparent modes in the size composition data.

Initial conditions

A model must assume something about the period prior to the start of the main population dynamics period. The same approach as the 2017 assessment was taken for initial model conditions in this study. Initial model conditions were estimated (where possible) assuming equilibrium catch. Initial fishing mortality rates were estimated for the F27 (Taiwanese longline in Areas 3 & 5) fishery because it captures a wide size range of albacore, but the initial fishing mortality rates were not fitted to historical catches prior to 1994. This approach allowed the model to start in 1994 at a depletion level that was consistent with the adult abundance index and size composition data without being overly constrained. In addition, the model included estimation of 15 recruitment deviations prior to 1994 to develop a non-equilibrium age structure at the start of the model time frame.

Model development

Numerous models were developed and evaluated during the model development process but most were evaluated to be side tracks or blind alleys and were discarded. Model development was focused on improving model fits, especially to the primary adult index (F9), as well as evaluating the model production function and R0 profiles. The major steps in the development of Model A that we considered useful are as follows:

1) Update data from 2017 to 2020, using the 2020 fishery definitions but otherwise similar to the 2017 assessment (e.g., mirrored selectivities for fisheries that were combined in the 2017 assessment, 2017 size data weightings).
2) Selectivity of fisheries that were split into seasonal fisheries (F10-F12; F14-16; F20-F21; and F22-F23) were allowed independent selectivities (using 2017 size data weightings).
3) Japan pole-and-line fleets in Q2 (F21) and Q3 (F22), which are the largest source of removals, are allowed to have annually varying age selectivity (if data are available).
4) Used alternative weighting scheme such that the weighting per sample was relatively equal between fisheries. Sample size multiplier of 0.1626 for all fisheries.
5) Evaluate conflicts between fishery-specific size composition data and the primary adult index; and evaluate the relative influence of the fishery-specific size composition data on the estimated population scale. Size composition data for specific fisheries were down-weighted or additional model processes incorporated, where appropriate.

In addition to the major model development steps highlighted above, we have also explored other model developments but more work is needed. These model developments were:

1) Fitting to the F1 juvenile/subadult index.
2) Use priors for steepness and natural mortality.

RESULTS AND DISCUSSION

The results and discussion section is organized by the model development steps highlighted above.

1) Update data from 2017 to 2020

The adult abundance indices used for both the 2017 and the current assessment are largely similar for the overlapping period (Fujioka et al. 2019) (Fig. 23). However, the estimated population scale for the model using 2020 data was slightly lower (Fig. 23). It should be noted that although we attempted to make both model structures as similar as possible (e.g., sharing the selectivities of fisheries that were originally a single fishery in the 2017 model), there were slight differences in the data and data weighting of each data component.

2) Selectivity of fisheries split into seasonal fisheries

Several multi-season fisheries in the 2017 assessment were split into seasonal fisheries (F10-F12; F20-F21; and F22-F23) to improve fits to the size composition data (Teo et al. 2019). In Step 1, these seasonal fisheries shared selectivity parameters, which is similar to acting as multi-season fisheries. Here, these fisheries were allowed to have independent selectivity parameters.

The changes in selectivity did not substantially affect the estimated SSB nor fit to the F9 adult index (Fig. 24). The changes to the length selectivity of the fisheries were relatively small, but there were larger changes in the age selectivities for the Japanese pole-and-line fisheries (F20 – F23). There were observable improvements to the fit to the size compositions of the fisheries involved, especially for F20 (Fig. 25).

3) Annually-varying age selectivities of F21 and F22

The Japanese pole-and-line fisheries for Quarter 2 and 3 (F21 and F22 respectively) have typically the largest catches of NPALB, and the modes in the size composition data vary substantially between years. It was suggested that the fits to the size composition for these two fleets be improved so that the removals at age are better represented in the model (Teo et al. 2019). In Step 3, the age selectivities of F21 and F22 were allowed to vary annually (Fig. 26), if the data are available, by using time blocks for each year.

Not surprisingly, overall model fit of the size composition data of F21 and F22 was substantially better (Fig. 27). However, the impact on model fit varies by year (Fig. 28). The impact on estimated population scale is relatively small but does appear to influence annual recruitment (Fig. 29). Including annually varying age selectivity also improves the fit to the adult index from -29.1 (Step 2) to -29.6 (Step 3) negative log-likelihood units (logL).

4) Alternative weighting scheme for size composition data

In the 2017 assessment, the weighting of the size composition data for each fishery were adjusted so that most fisheries were roughly equal in weighting with average input sample sizes of ~7. However, that resulted in the relatively low weighting per sample for well-sampled fisheries as compared with less sampled fisheries. For example, weighting per unit sample for F25 in the Step 3 model would be approximately 26x higher than for the best-sampled fishery, F1. During the 2017 assessment, the size composition data for Japanese longline fisheries in Areas 2 and 4 (F9, F10, F11, F12, and F17) and both US longline fisheries (F25 and F26) were further down-weighted by using lambda factors of 0.1 in order to improve the fit to the abundance index. In effect, the average input sample size for these fisheries were ~0.7.

In this part of the study (Step 4), we investigate the effect of an alternative initial weighting scheme such that the weighting per sample was relatively equal between fleets. The input sample sizes of the best-sampled fishery (F1_JPLL_A13_Q1) were rescaled by a multiplier of 0.1626, such that the average input sample size for F1 was ~30. The same multiplier was then used for all fisheries. In order to compare the effect of this alternative weighting scheme, we compared the model fit of this Step 4 model, especially the adult index of F9, to both the Step 3 model and the Step 3 model with all size composition lambda factors at 1 (Step 3b). Comparing to the Step 3b model will be a fairer comparison because all size composition lambda factors will be at 1 for both models.

The Step 4 model resulted in fits to the F9 index (-28.2 logL) that was better than the Step 3b model (-26.7 logL) but poorer than the Step 3 model (-29.6 logL) (Fig. 30). The largest differences in the estimated population dynamics appeared to be at the start of model (Fig. 30). In addition, the decline in the recruitment during 2014 and 2015 appears to be more substantial in the Step 4 model (Fig. 30). However, the effect of the changes in weighting did not substantially change the estimated depletion in recent years (Fig. 30). The comparison of these models illustrate the importance of size composition weighting on the estimated population dynamics, especially the early part of the model, but the effect on management quantities for the assessment may be more limited. It is currently difficult to be definitive which initial weighting scheme is more appropriate because both schemes have pros and cons, and will clearly be a subject of discussion during the assessment meeting. The 2017 weighting scheme allows the ALBWG to have better control on the weighting of each size composition component but likely overweighted the less well-sampled fisheries initially. The alternative initial weighting scheme better represents the relative weighting of the sampling of the fisheries but results in very different initial sample sizes for each fishery, which leads to more difficulty in teasing apart the effect of each size composition component. Given the improvement of fit to the F9 index compared to the Step3b model, we decided to continue from the Step 4 model but this decision should be revisited by the ALBWG.

5) **Conflicts between size composition data and the adult index, and model diagnostics (age-structured production model and R0 profile analysis)**

During the 2017 assessment, the ALBWG determined that the size composition data for Japanese longline fisheries in Areas 2 and 4 (F9, F10, F11, F12, and F17) and both US longline fisheries (F25 and F26) had conflicts with the adult index and were down-weighted. Here, we do a similar analysis to identify the fisheries with size composition that conflicted with the adult index. The adult index is upweighted using a lambda factor of 5 and the likelihood components of each fishery are then examined to identify the size composition data components that conflict with it. In addition, we also conduct age-structured production model (ASPM) and R0 profile analyses to diagnose the models.

The above analysis indicated that the size composition data of F9, F22, and F33 were the most inconsistent with the F9 index (Table 2). Subsequently, we downweighted the size composition of each of these fisheries to examine the impact on the F9 index. Downweighting the F9 size compositions improved the fit to the F9 index slightly (-28.2 to -28.6 logL) but had only minor effects on the estimated population dynamics (Fig. 31). Downweighting the F21 and F22 size compositions were done together as they were closely related fisheries and the R0 profile suggested that both fleets were relatively influential on the estimated population scale. Downweighting the F21 and F22 size compositions resulted in lower estimated population scale but improved the fit to the F9 index (-28.2 to -29.3 logL) (Fig. 32). However, some strata of size composition data for these fleets became badly misfit (Fig. 32). Downweighting the F33 size compositions improved the fit to the F9 index slightly (-28.2 to -28.5 logL) but had only minor effects on the estimated population dynamics (Fig. 33). For this study, we chose not to downweight the F21 and F22 size composition data because the size composition data became poorly fit and these were the two largest fisheries. We also chose not to downweight the F33 size composition data because the F33 was one of the largest fisheries and using time-varying selectivity may be a better option for this fishery.

The R0 profile of the Step 4 model indicated several fisheries (F1, F21, F22, F27) had relatively large influence on the estimated population scale (Fig. 34). However, downweighting the F21 and F22 size composition data resulted in poor fits to the size composition data. We did not consider downweighting the F1 size composition data because the upweighting analyses indicated that the F1 size composition data were consistent with the adult abundance index. Therefore, based on the R0 profile analysis, we only downweighted the F27 size composition data.

The Step 5 model primarily consisted of the Step 4 model with the additional downweighting of the F9 and F27 size composition data. In addition, the peak parameter of the length selectivity of the F26 fishery and several age selectivity parameters of the F21, F22 and F33 fisheries tended to hit parameter bounds, and these bounds were adjusted so that these bounds were tested less often. In adjusting the bound of the peak parameter of the F26 fishery, the maximum population length had to be adjusted from 144 cm to 150 cm.

An ASPM analysis was used on the Step 5 model to examine the production function of the model. The Step 5 model was found to have a reasonably well observed production function (Fig. 35). This means that the catch time series and estimated productivity can explain much of the changes in the observed population, and adds confidence that the estimated population scale is approximately right. In addition, the minima of the R0 profile for the adult abundance index is approximately in the right region as the maximum likelihood estimate of the R0 of the Step 5 model (~12.0).

Overall, we believe that the Step 5 model was a reasonable starting point for the ALBWG to develop the 2020 assessment of NPALB. The model files for this model were provided to the ALBWG prior to the assessment meeting and can be used to continue development.

Additional models

The ALBWG had recommended that the F1 index (Fig. 3) be explored as a potential abundance index for juvenile/subadult albacore in Area 1 because the F1 and F9 index appeared to be correlated with a lag (ALBWG 2019; Fujioka et al. 2019). In addition, fitting to the F1 index resulted in the improvement of fit to the F9 index. However, an ASPM fitting to both the F1 and F9 indices do not result in a converged model, which suggests that there is a conflict in the production function of the F1 and F9 indices. Therefore, unless this issue is resolved, we do not recommend fitting to the F1 index for the 2020 assessment.

As recommended by the ALBWG, we also explored the use of priors for M and h instead of fixed parameters. Early model runs suggested that models with both M and h priors were converging. The results suggested that there appeared to be negligible information in the data to inform the highly informative h prior. The models also estimated reasonable M values for female albacore (0.71 y^{-1}) with a fixed offset for the males, resulting in an M of (0.57 y^{-1}) for the males. However, much more work needs to be done to explore the use of these priors.

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Table 1. Fishery definitions for this study. Availability of size and abundance index data is indicated in the notes. * indicates that size or index data were available but were not fitted in the base case model. Two letter country codes are used in the fishery name: JP = Japan; US = United States of America; TW = Chinese-Taipei; KR = Korea; and VU = Vanuatu and Others.

ID	Fishery name	Area	Primary gear	Quarter	Catch unit	Notes
F1	F1_JPLL_A13_Q1_wt	1 & 3	Longline	1	Tonnes	Size, Index*
F2	F2_JPLL_A13_Q2_wt	1 & 3	Longline	2	Tonnes	Size
F3	F3_JPLL_A13_Q3_wt	1 & 3	Longline	3	Tonnes	Size
F4	F4_JPLL_A13_Q4_wt	1 & 3	Longline	4	Tonnes	Size
F5	F5_JPLL_A13_Q1_num	1 & 3	Longline	1	1000s	
F6	F6_JPLL_A13_Q2_num	1 & 3	Longline	2	1000s	
F7	F7_JPLL_A13_Q3_num	1 & 3	Longline	3	1000s	
F8	F8_JPLL_A13_Q4_num	1 & 3	Longline	4	1000s	
F9	F9_JPLL_A2_Q1_wt	2	Longline	1	Tonnes	Size, Index
F10	F10_JPLL_A2_Q2_wt	2	Longline	2	Tonnes	Size
F11	F11_JPLL_A2_Q3_wt	2	Longline	3	Tonnes	Size
F12	F12_JPLL_A2_Q4_wt	2	Longline	4	Tonnes	Size
F13	F13_JPLL_A2_Q1_num	2	Longline	1	1000s	
F14	F14_JPLL_A2_Q2_num	2	Longline	2	1000s	
F15	F15_JPLL_A2_Q3_num	2	Longline	3	1000s	
F16	F16_JPLL_A2_Q4_num	2	Longline	4	1000s	
F17	F17_JPLL_A4_wt	4	Longline	All	Tonnes	Size
F18	F18_JPLL_A4_num	4	Longline	All	1000s	
F19	F19_JPLL_A5_num	5	Longline	All	1000s	Size
F20	F20_JPPL_A3_Q1	3	Pole & line	1	Tonnes	Size
F21	F21_JPPL_A3_Q2	3	Pole & line	2	Tonnes	Size, Index*
F22	F22_JPPL_A3_Q3	3	Pole & line	3	Tonnes	Size
F23	F23_JPPL_A3_Q4	3	Pole & line	4	Tonnes	Size
F24	F24_JPPL_A2	2	Pole & line	All	Tonnes	Size
F25	F25_USLL_A35	3 & 5	Longline	All	Tonnes	Size
F26	F26_USLL_A24	2 & 4	Longline	All	Tonnes	Size
F27	F27_TWLL_A35	3 & 5	Longline	All	Tonnes	Size, Index*
F28	F28_TWLL_A24	2 & 4	Longline	All	Tonnes	
F29	F29_KRLL	All	Longline	All	Tonnes	
F30	F30_CNLL_A35	3 & 5	Longline	All	Tonnes	Size*
F31	F31_CNLL_A24	2 & 4	Longline	All	Tonnes	Size*
F32	F32_VUOTHLL	All	Longline	All	Tonnes	Size*
F33	F33_EPOSF	3 & 5	Surface	All	Tonnes	Size
F34	F34_JPKRTW_DN	All	Drift net	All	Tonnes	
F35	F35_JPTW_MISC	All	Misc	All	Tonnes	

Table 2. Changes in the log-likelihood (logL) of size composition data components when the adult index (F9) is upweighted by a factor of 5 (lambda=5). Negative numbers indicate a component is consistent with the index, while positive numbers indicate otherwise. For each model, the three largest changes in logL are highlighted in yellow, indicating the components that are the most inconsistent with the adult index. * indicates components with a lambda factor of 0.1. Comparisons should only be made between fisheries within models due to different weightings in each model.

Model	F1 size	F2 size	F3 size	F4 size	F9 size	F10 size	F11 size	F12 size	F17 size	F19 size
Step 3	-1.06	-0.29	0.48	1.17	1.20*	0.08*	0.03*	0.12*	0.28*	-0.13
Step 3b	-1.15	-0.09	0.03	0.40	0.47	0.63	0.05	0.56	2.29	-0.10
Step 4	-0.01	0.14	0.02	0.72	1.34	0.55	0.19	0.57	0.18	-0.03

Model	F20 size	F21 size	F22 size	F23 size	F24 size	F25 size	F26 size	F27 size	F33 size
Step 3	-0.05	0.39	0.55	1.02	1.19	0.05*	0.29*	-0.24	0.25
Step 3b	-0.08	0.13	0.18	0.01	1.48	0.05	3.04	-0.35	0.54
Step 4	0.05	0.85	3.10	-0.07	0.16	0.02	0.29	0.51	0.96

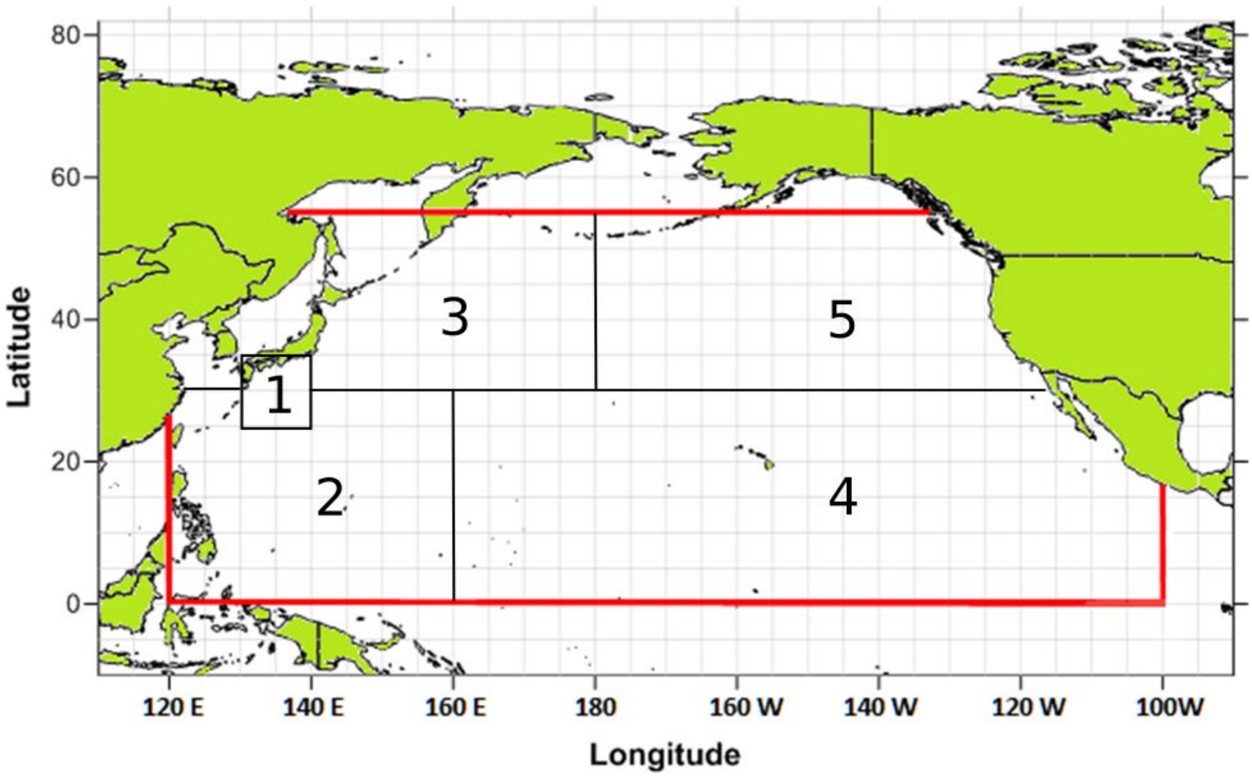

Figure 1. Spatial domain (red box) of the north Pacific albacore stock (*Thunnus alalunga*) in the 2020 stock assessment. Fishery definitions were based on five fishing areas (black boxes and numbers) defined from cluster analyses of size composition data.

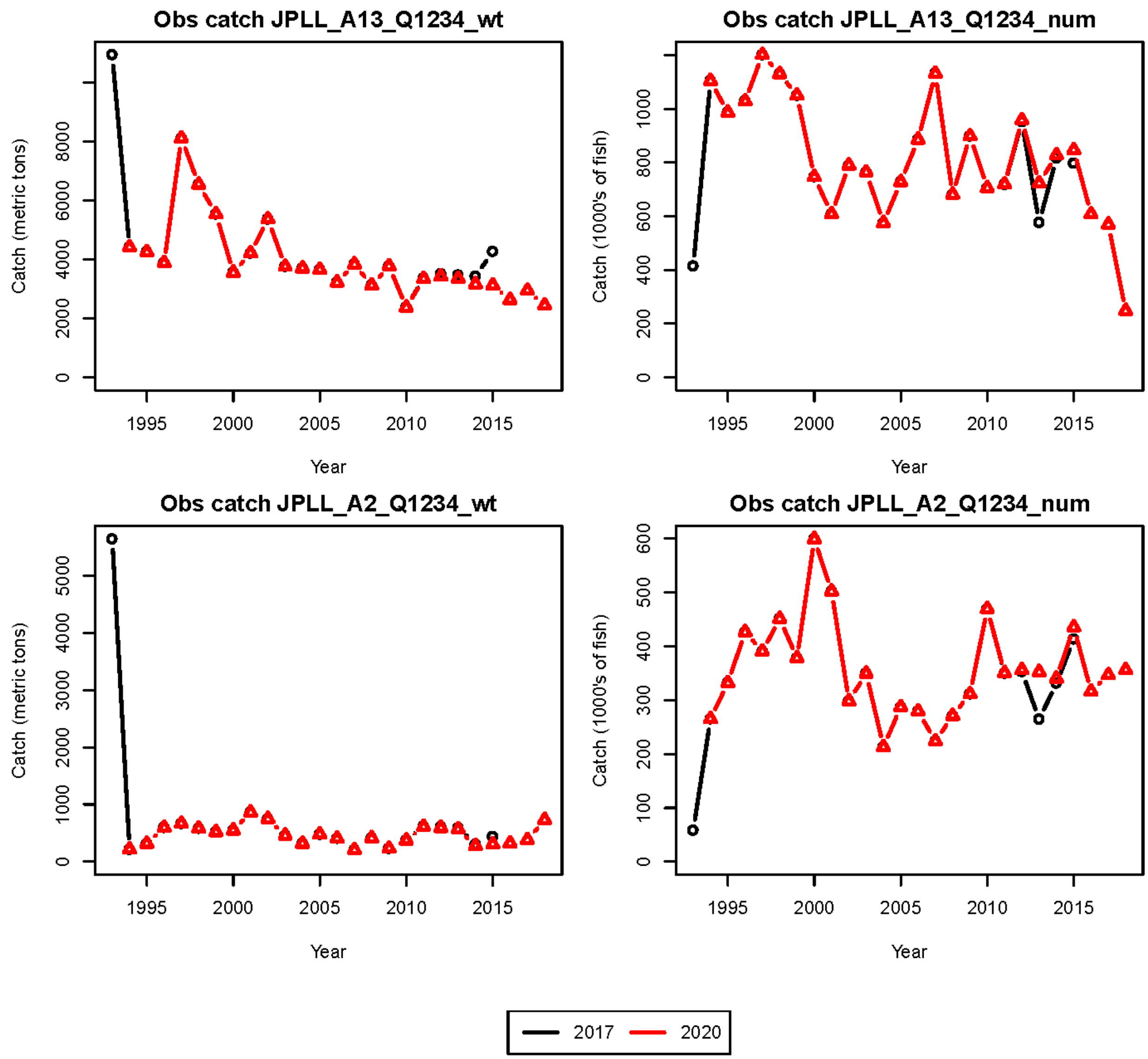

Figure 2. Comparison of the annual catch time series between the 2017 (black) and 2020 (red) models. Fisheries are grouped by flag, gear, area and catch unit (Table 1). Seasonal fisheries are combined for plotting convenience. For example, F1 through F4 are grouped together in the upper left panel (JPLL_A13_Q1234).

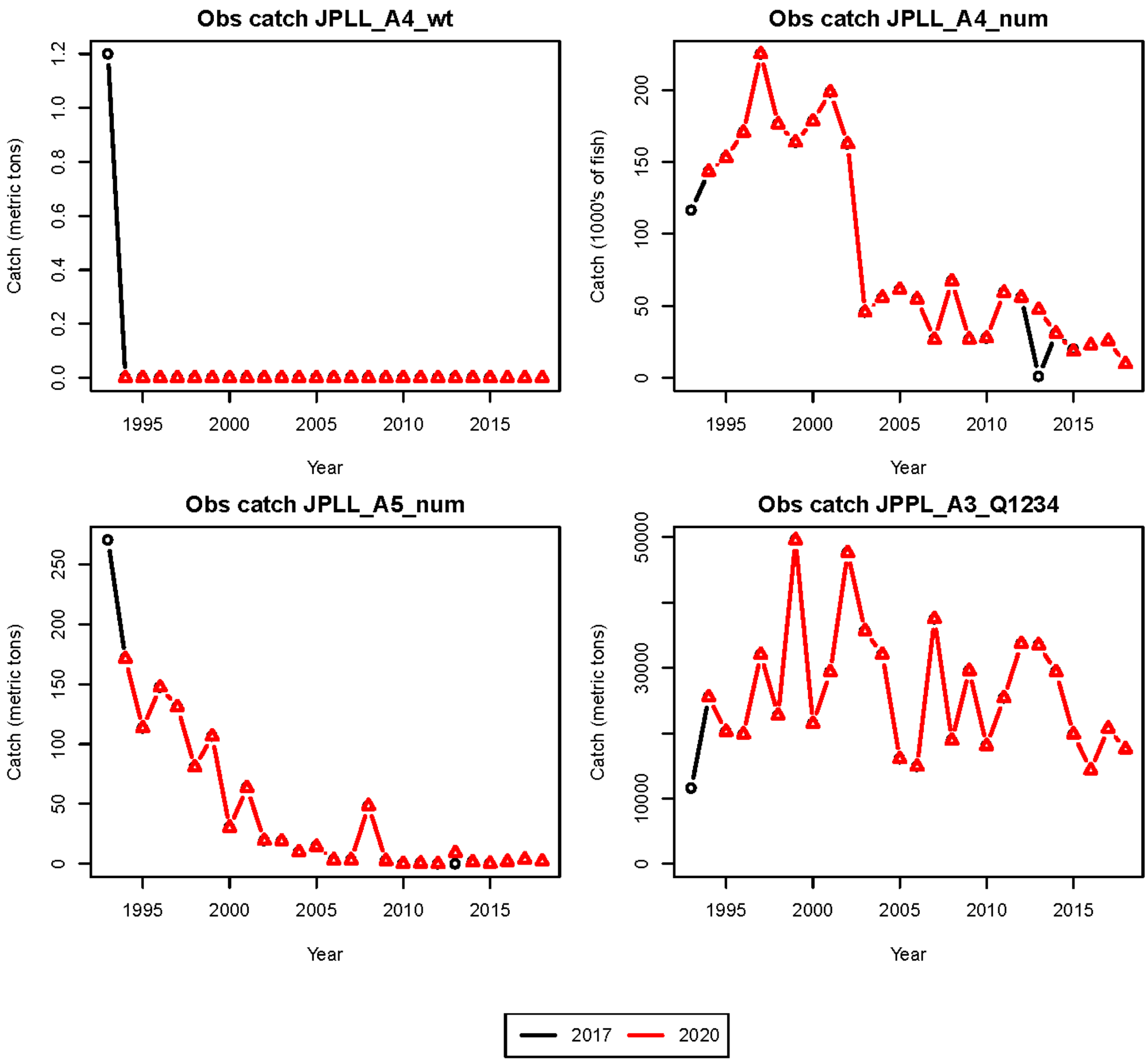

Figure 2. Continued.

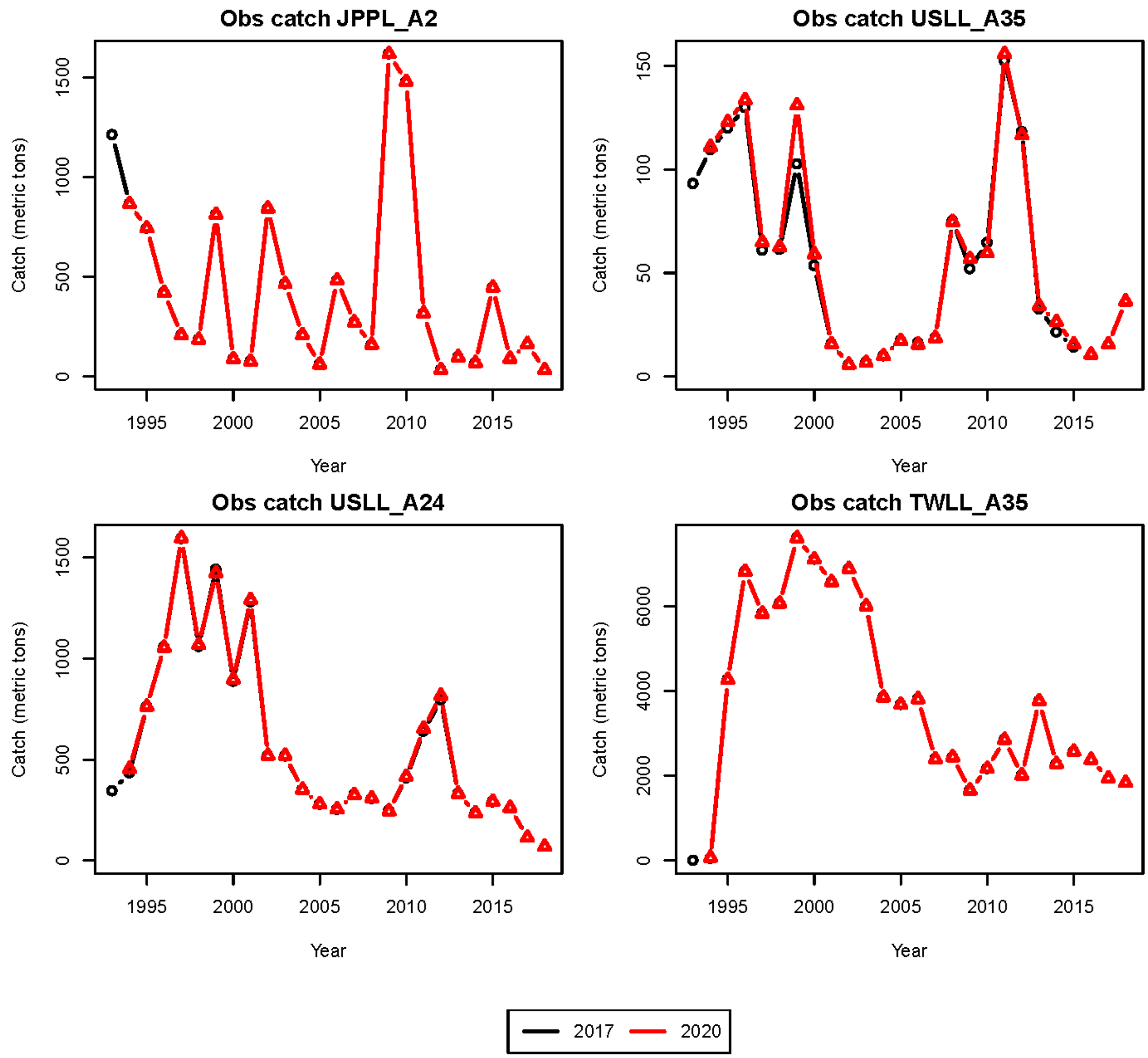

Figure 2. Continued.

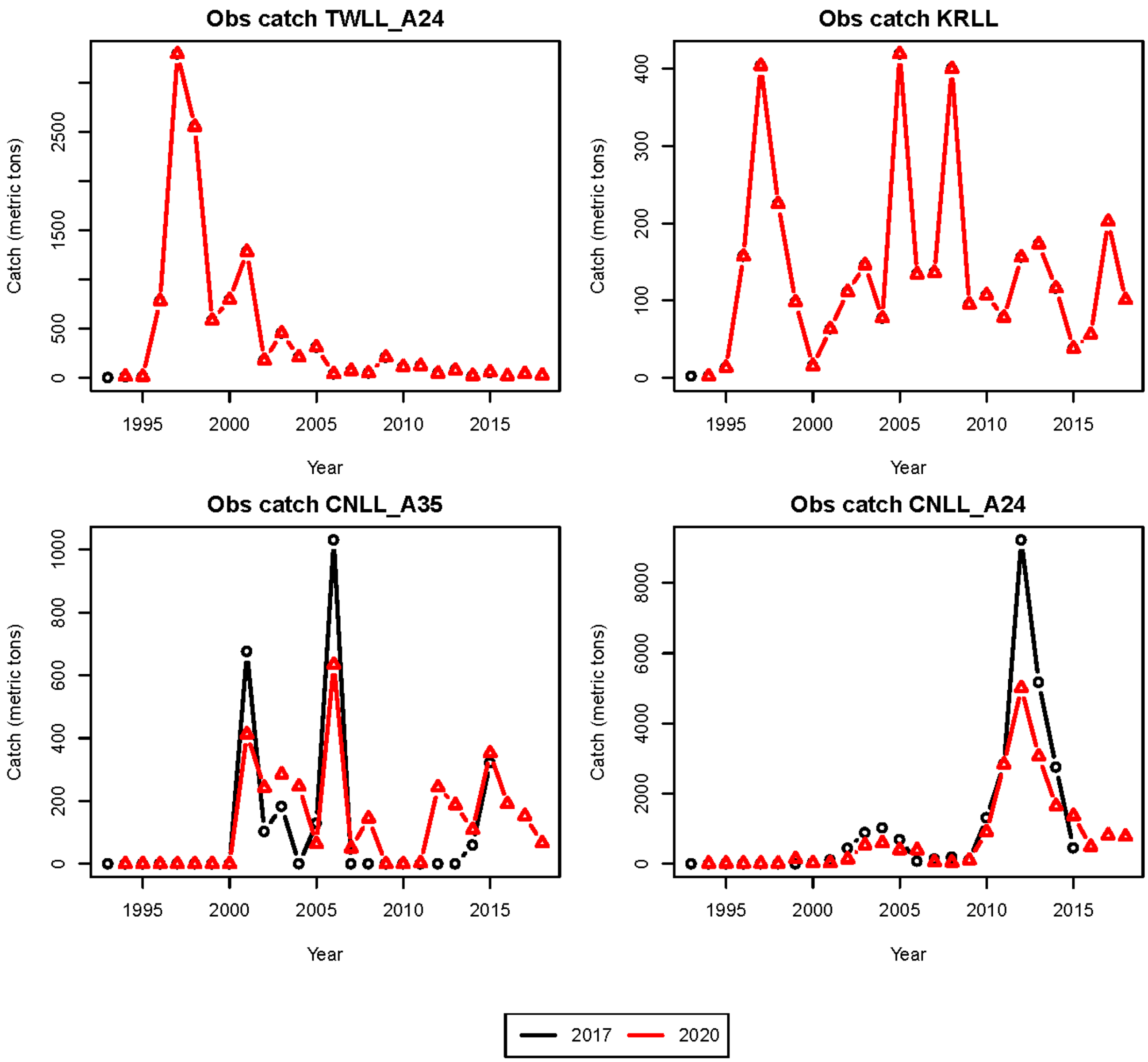

Figure 2. Continued.

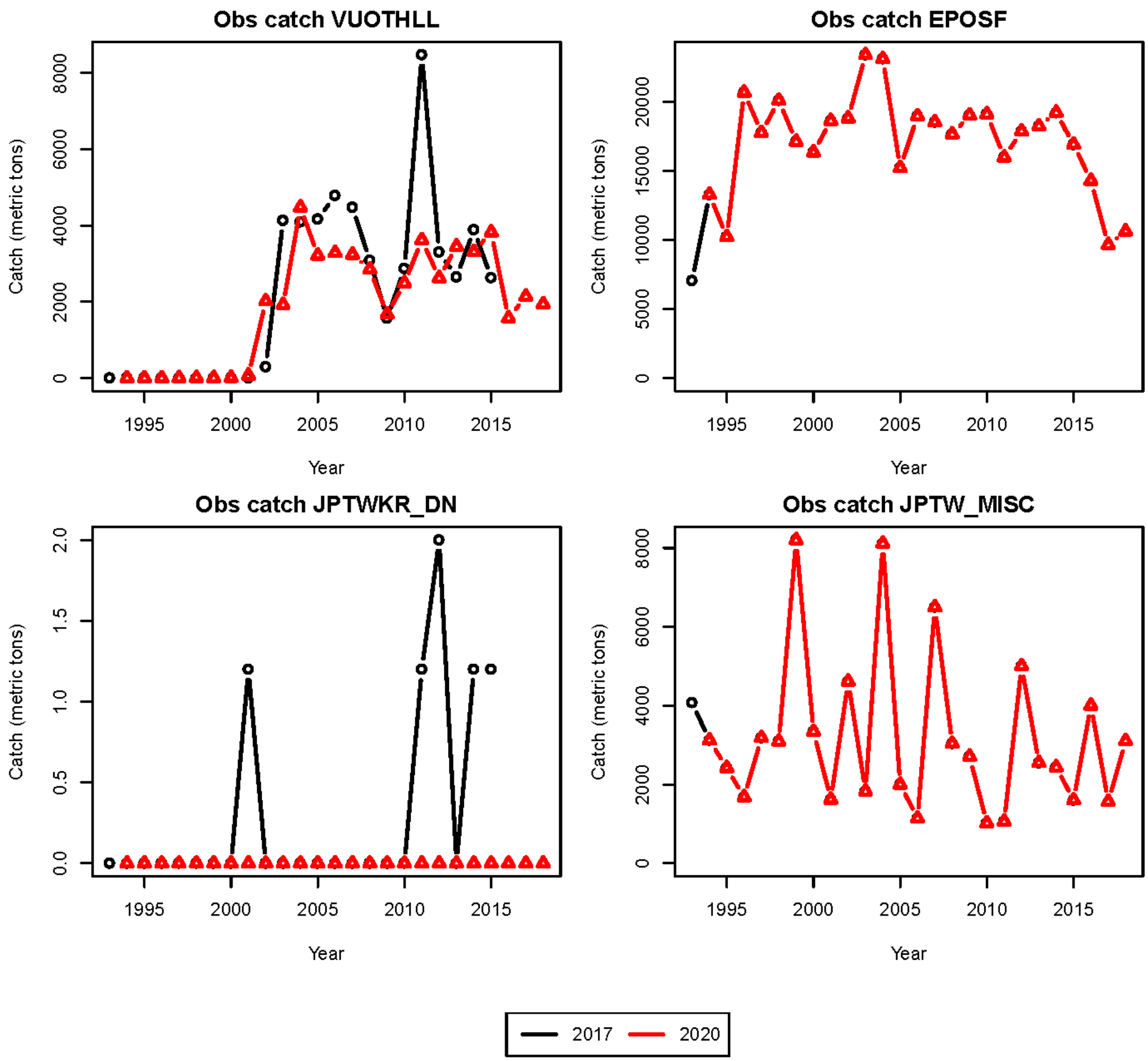

Figure 2. Continued.

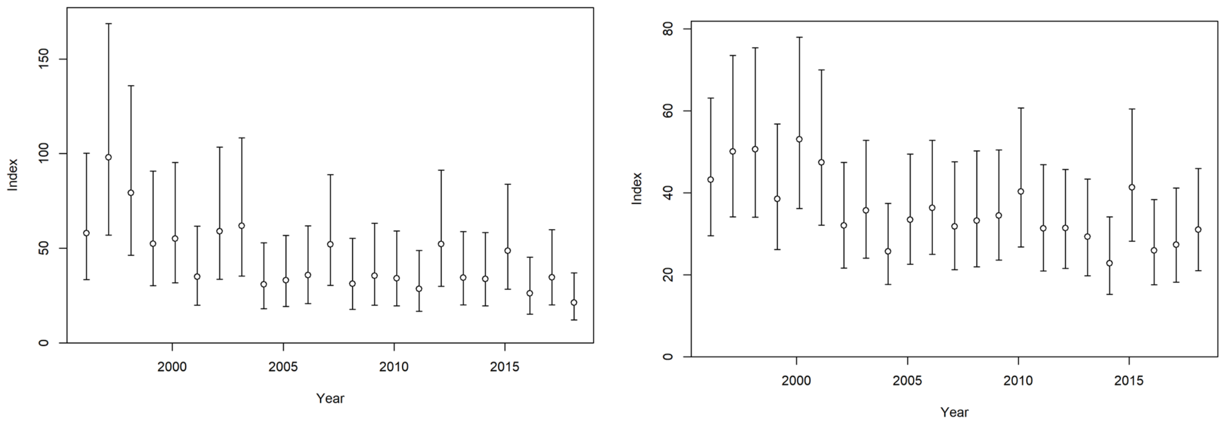

Figure 3. Trends and coefficients of variation (CVs; input + additional CVs) of the F1 (left panel; juvenile/subadult) and F9 (right panel; adult) indices used in this study.

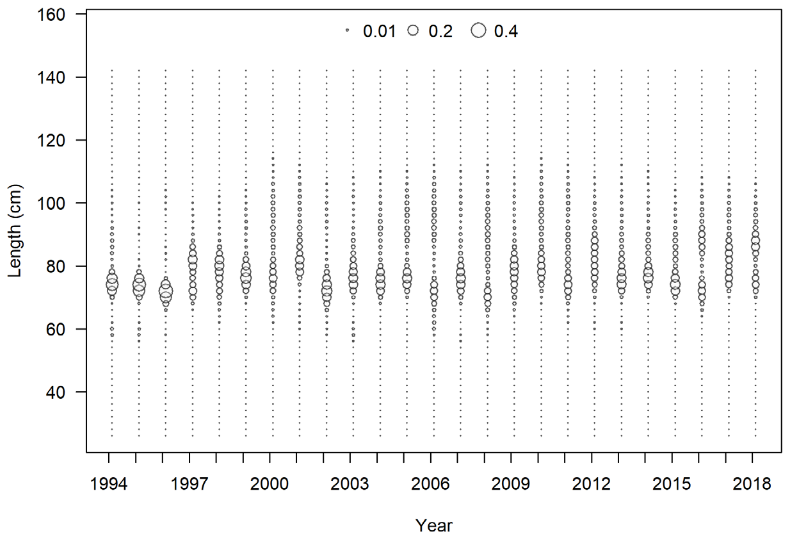

Figure 4. Size composition data for F1_JPLL_A13_Q1.

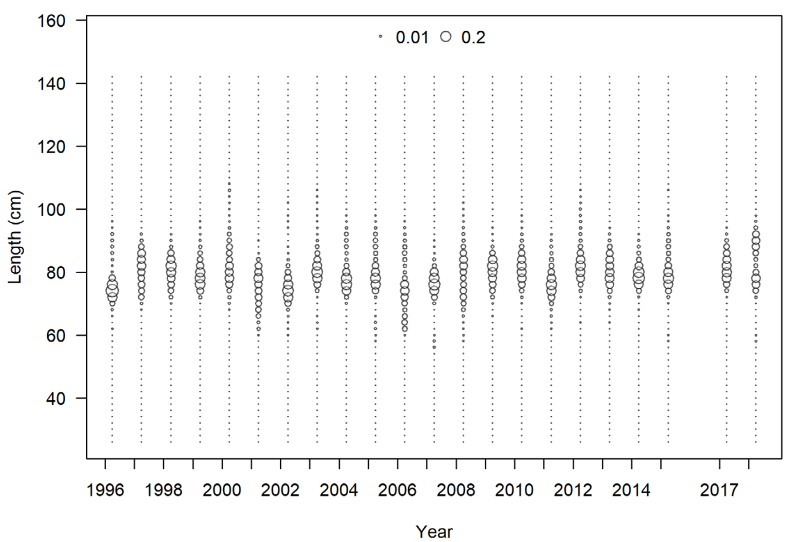

Figure 5. Size composition data for F2_JPLL_A13_Q2.

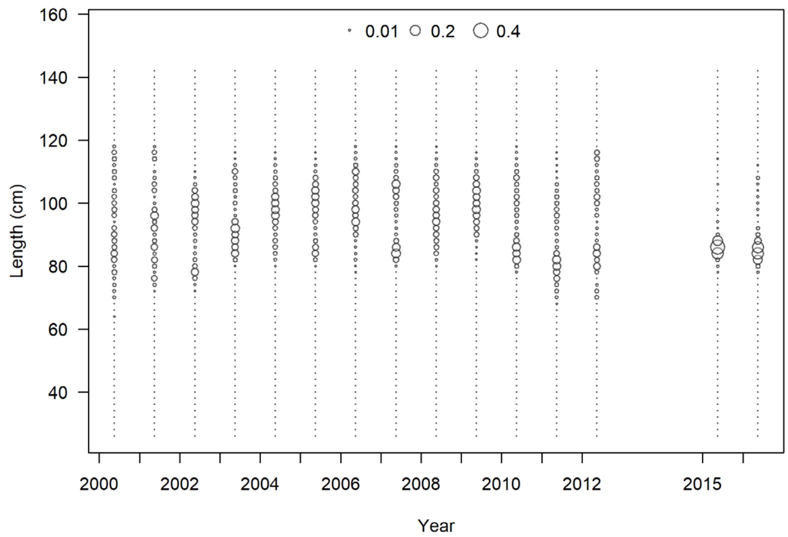

Figure 6. Size composition data for F3_JPLL_A13_Q3.

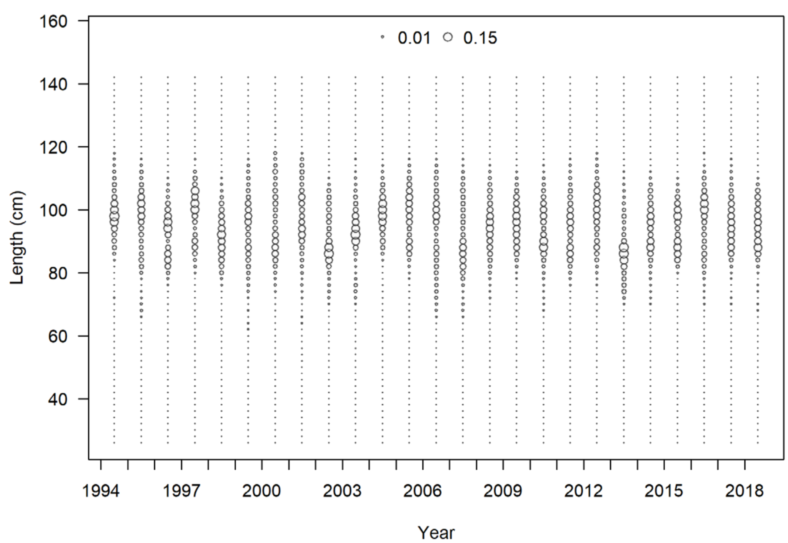

Figure 7. Size composition data for F4_JPLL_A13_Q4.

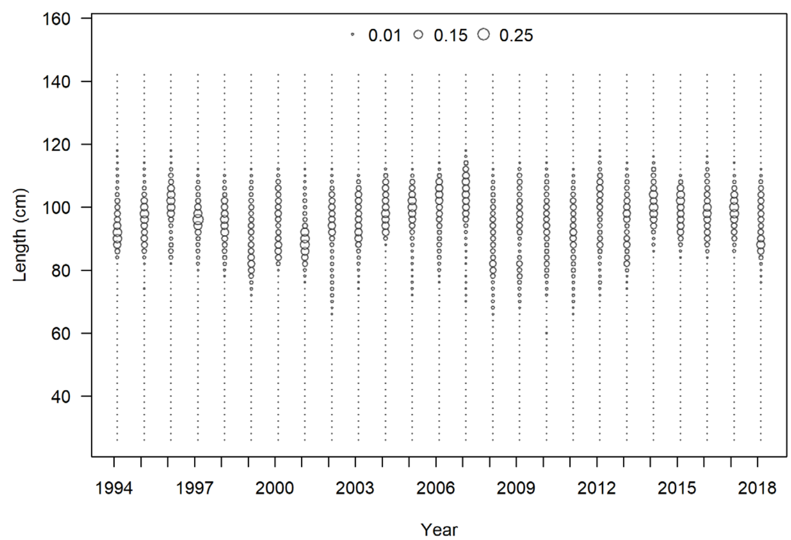

Figure 8. Size composition data for F9_JPLL_A2_Q1.

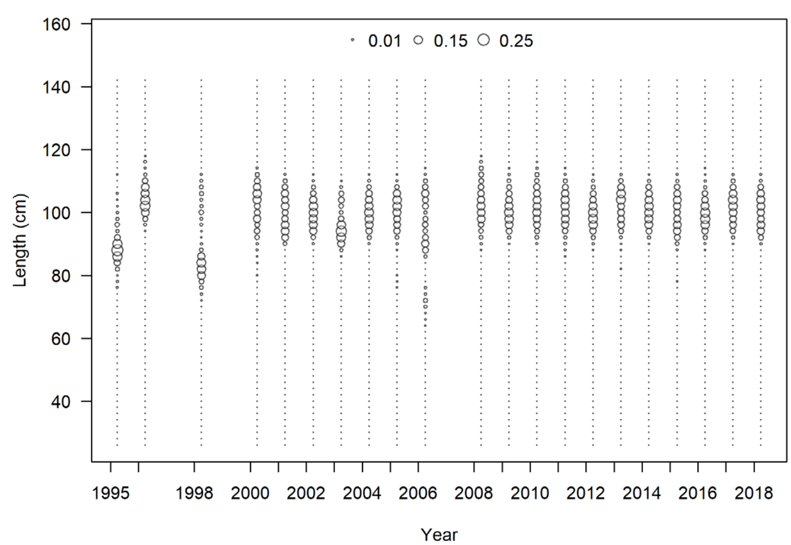

Figure 9. Size composition data for F10_JPLL_A2_Q2.

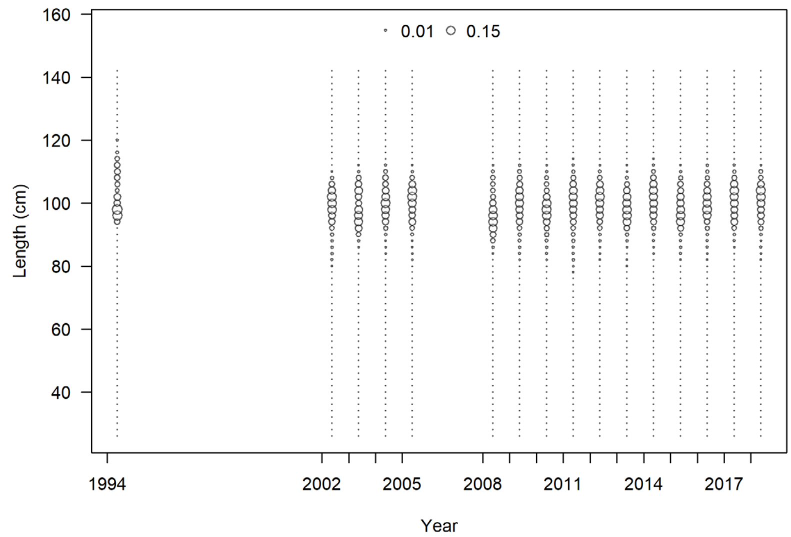

Figure 10. Size composition data for F11_JPLL_A2_Q3.

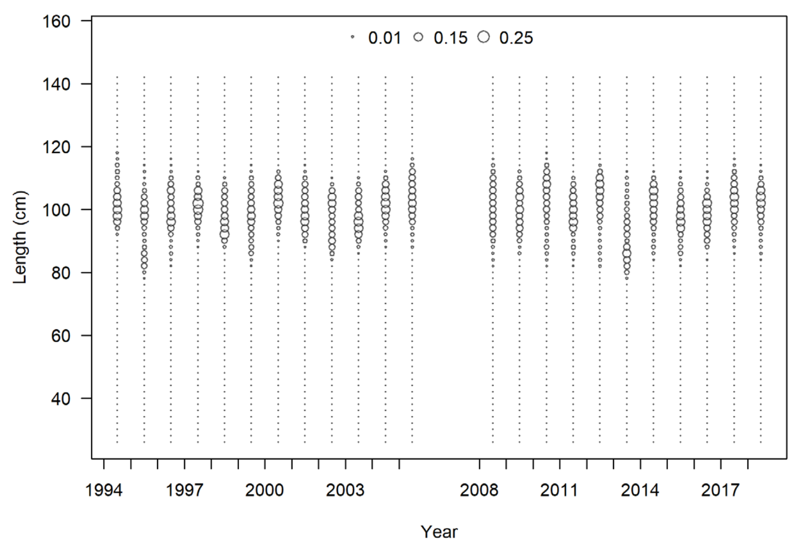

Figure 11. Size composition data for F12_JPLL_A2_Q4.

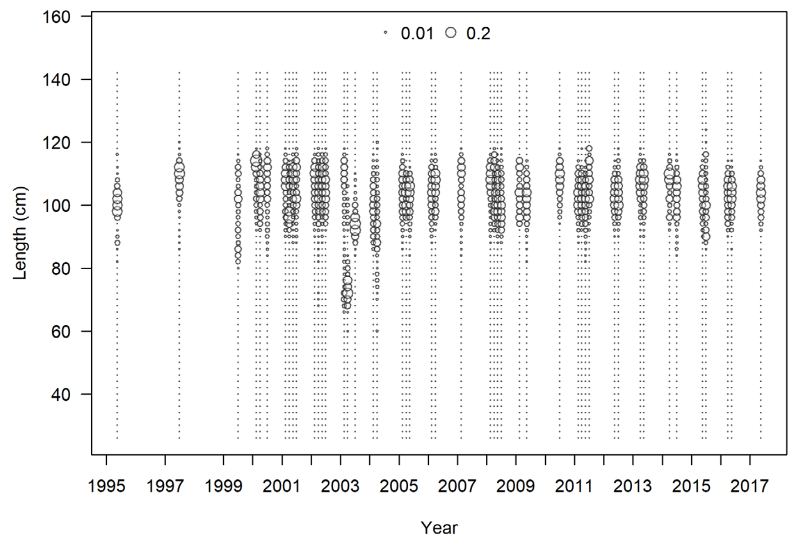

Figure 12. Size composition data for F17_JPLL_A4.

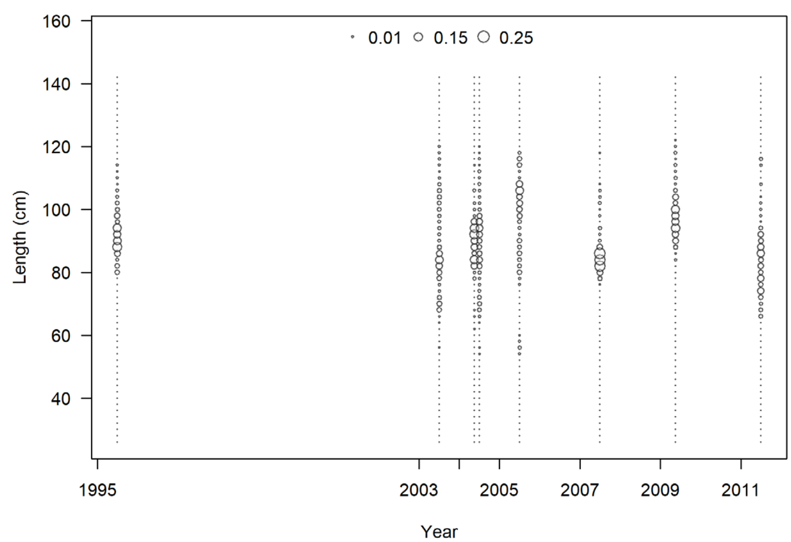

Figure 13. Size composition data for F19_JPLL_A5.

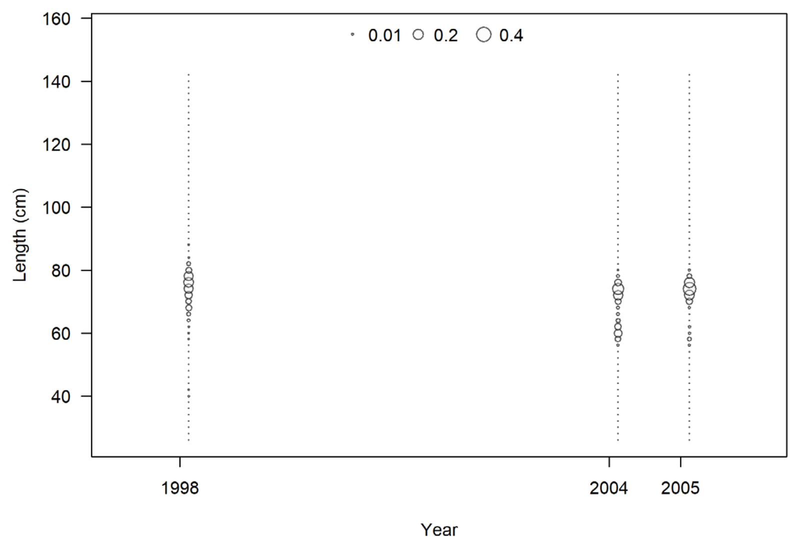

Figure 14. Size composition data for F20_JPPL_A3_Q1.

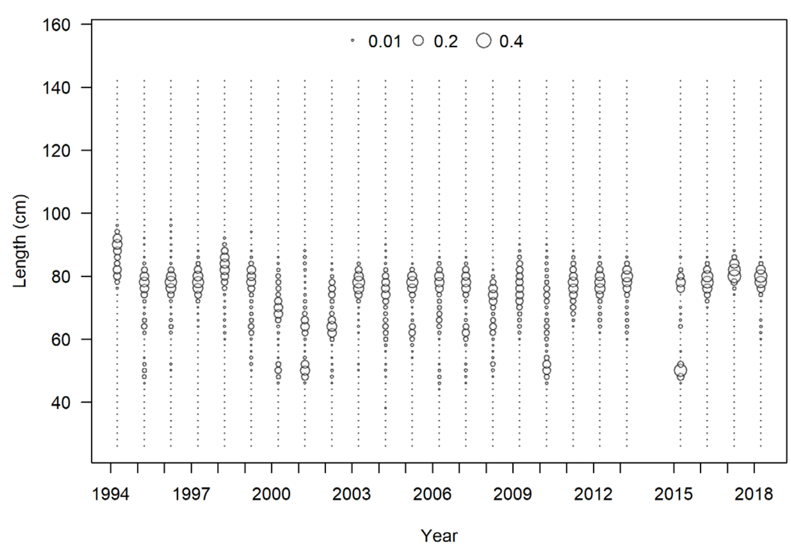

Figure 15. Size composition data for F21_JPPL_A3_Q2.

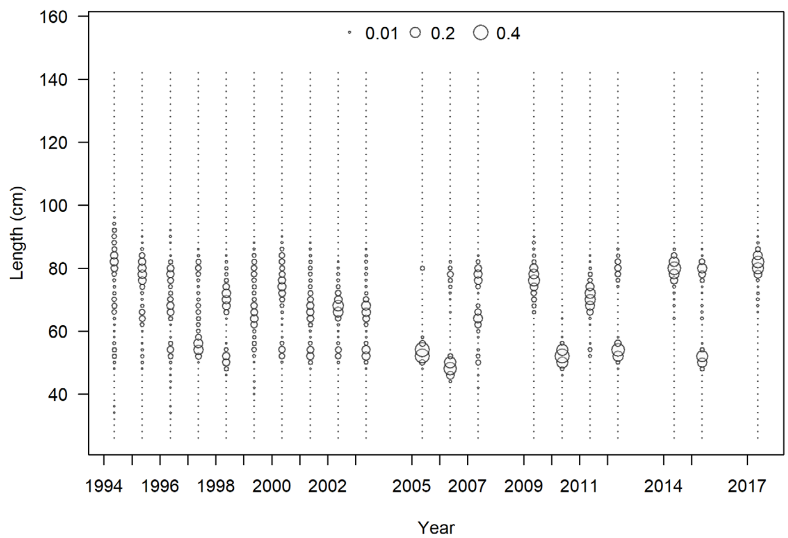

Figure 16. Size composition data for F22_JPPL_A3_Q3.

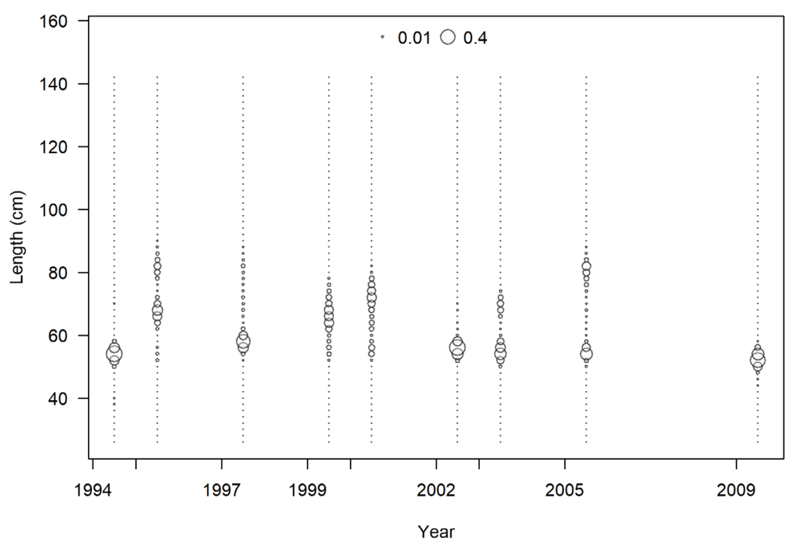

Figure 17. Size composition data for F23_JPPL_A3_Q4.

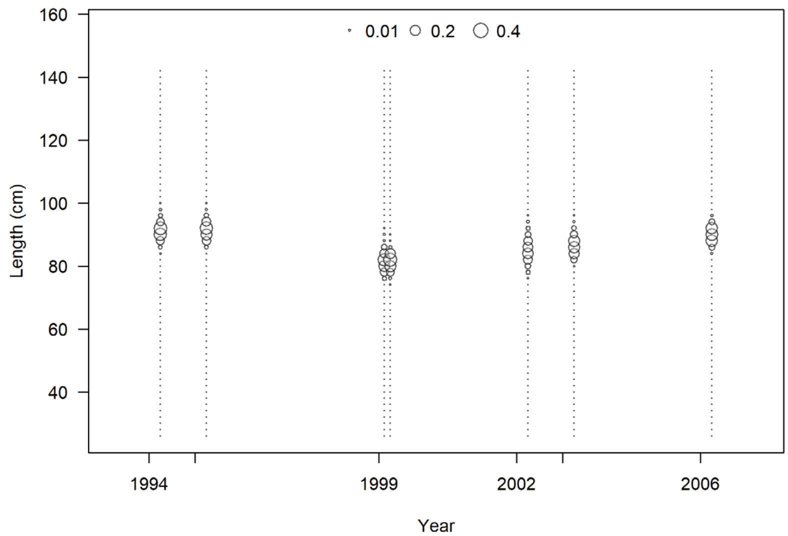

Figure 18. Size composition data for F24_JPPL_A2.

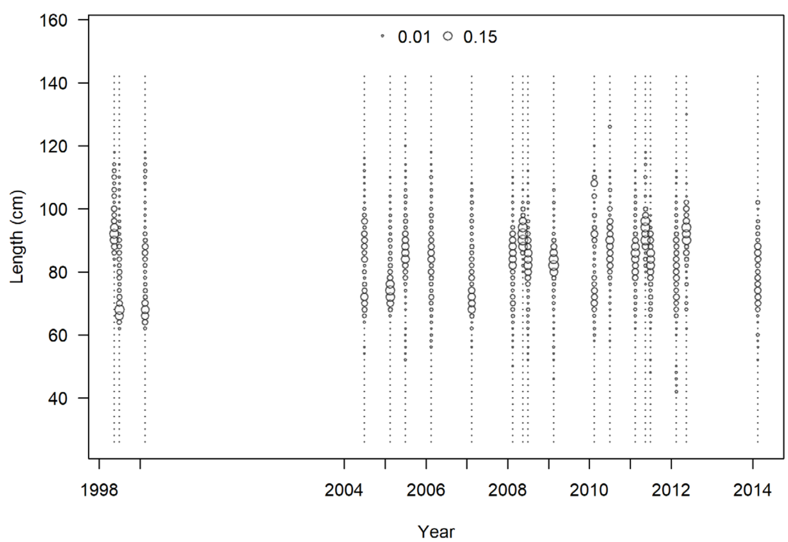

Figure 19. Size composition data for F25_USLL_A35.

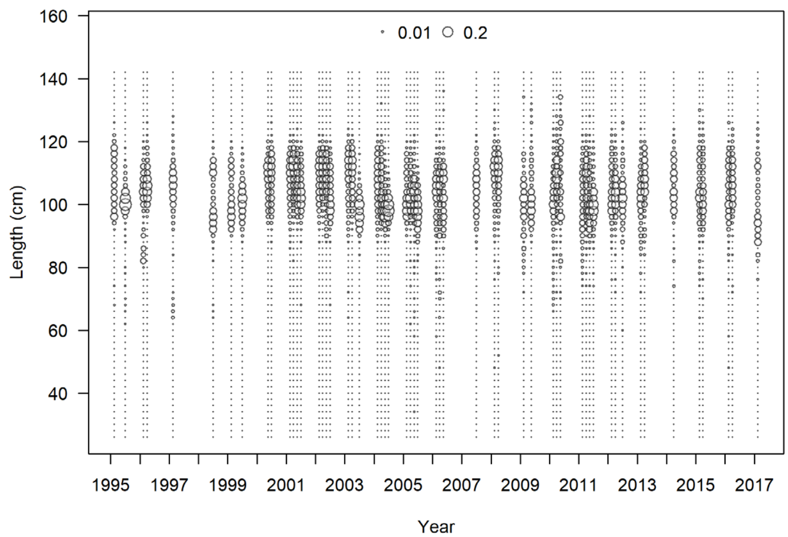

Figure 20. Size composition data for F26_USLL_A24.

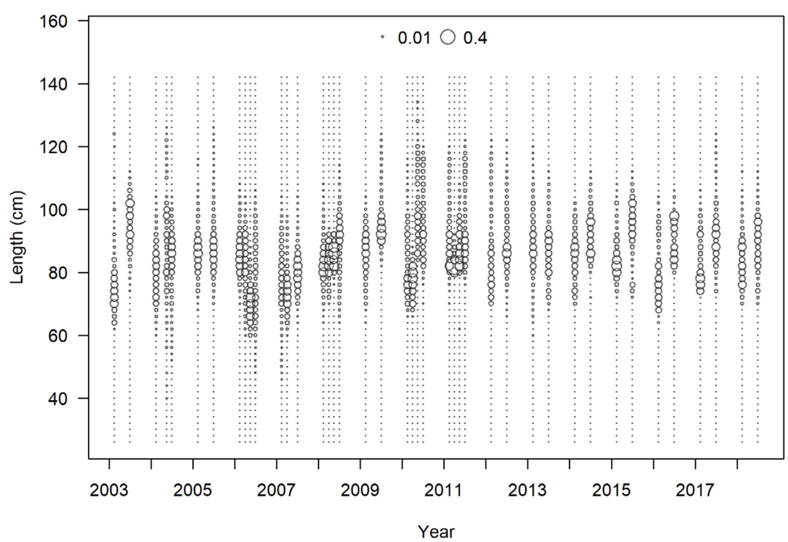

Figure 21. Size composition data for F27_TWLL_A35.

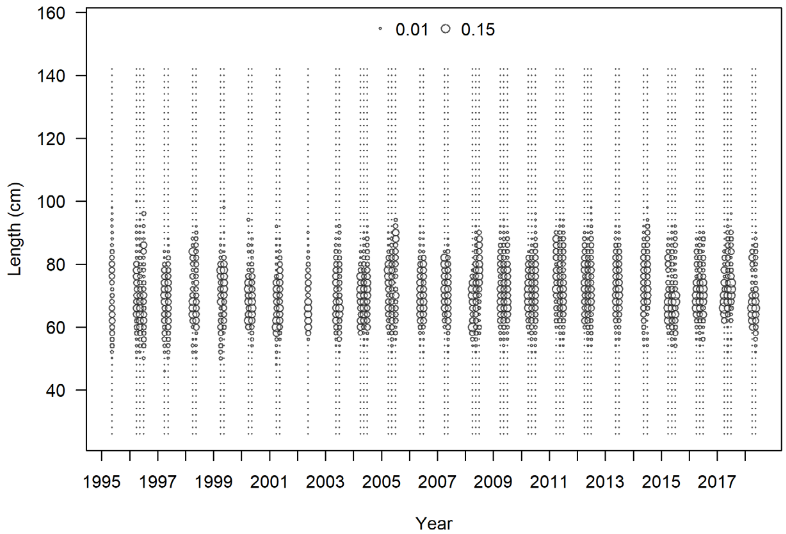

Figure 22. Size composition data for F33_EPOSF.

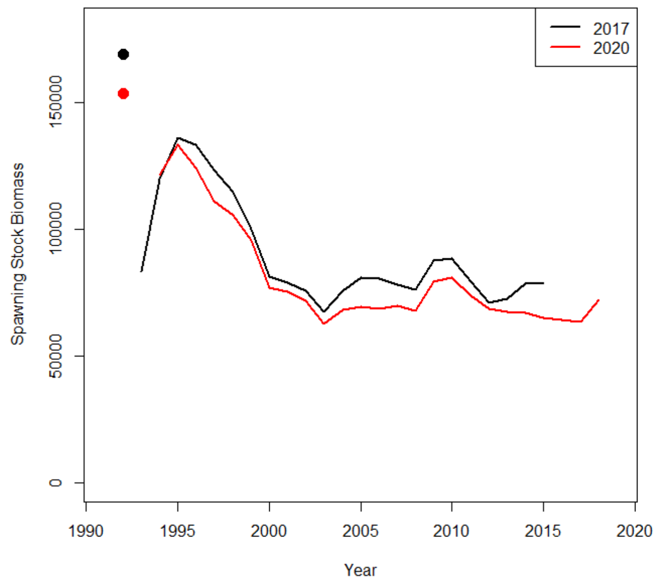

Figure 23. Comparison of estimated female SSB (upper) and adult indices (lower) between a model similar to the 2017 base case model (black; 1993 – 2015) and a model with similar model structure but with data for the 2020 assessment (red; 1994 – 2018).

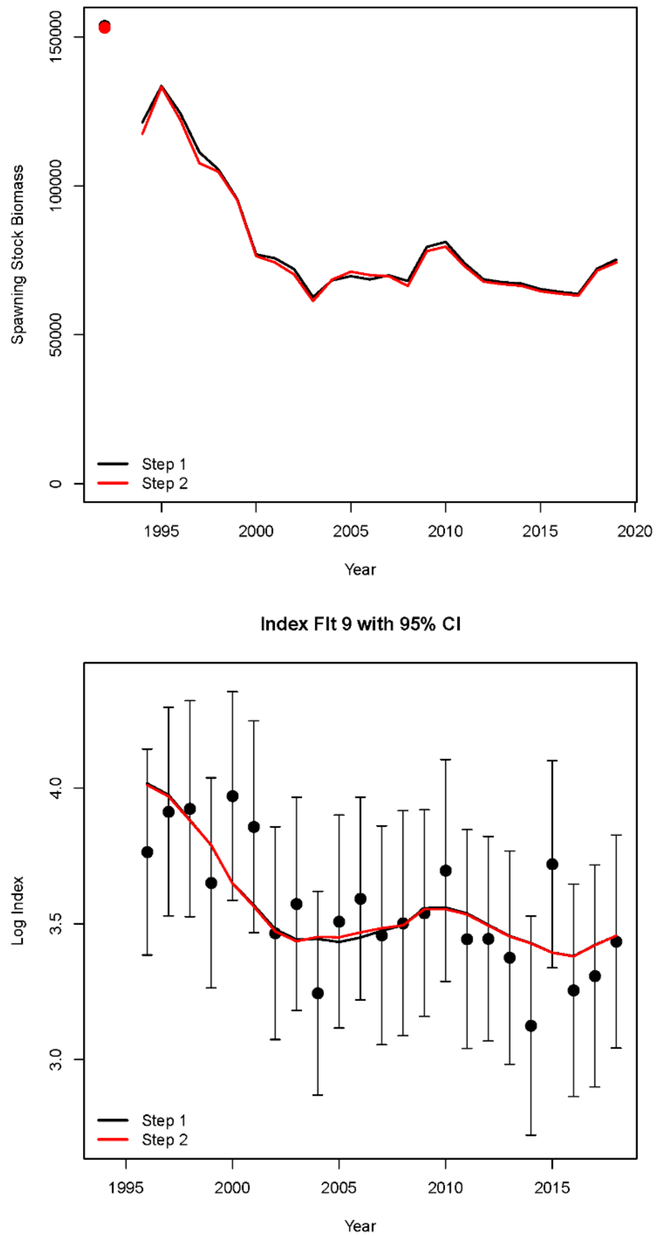

Figure 24. Comparison of estimated female SSB (upper) and fit to adult index (lower) between a model that is similar to the 2017 model in structure, but using 2020 data (black; Step 1) and a model with several fisheries in the 2017 assessment were split into seasonal fisheries (F10-F12; F14-16; F20-F21; and F22-F23) (red; Step 2).

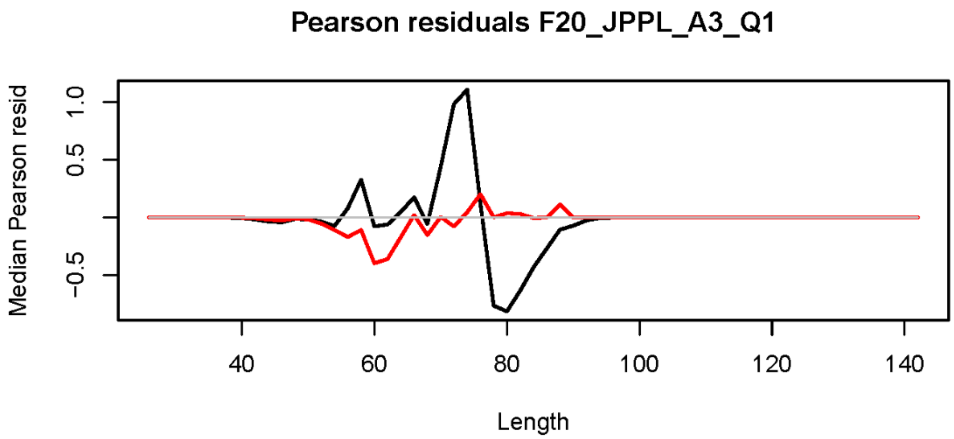

Figure 25. Median of Pearson residuals for Japanese pole-and-line fishery in Area 2 in Quarter 1 (F20) between the Step 1 (black) and Step 2 (red) models.

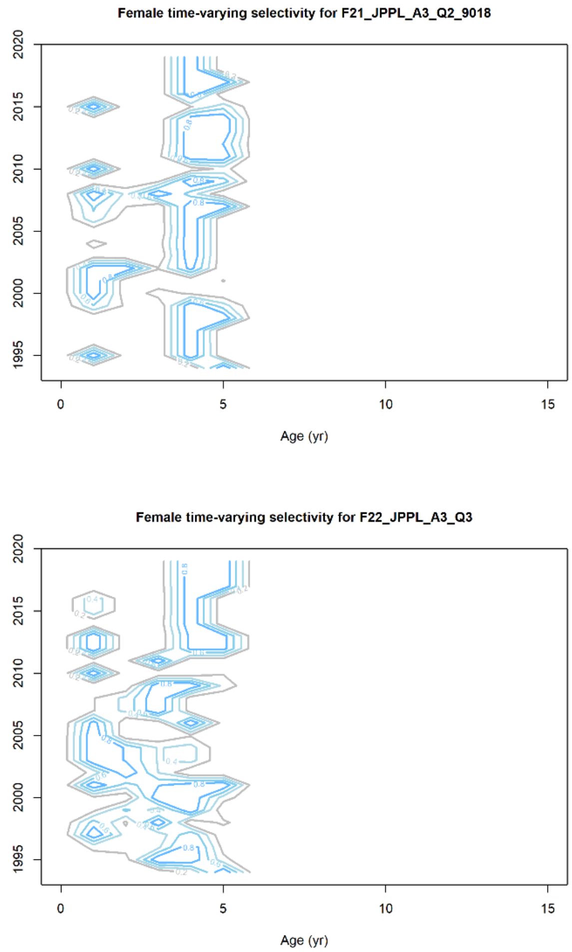

Figure 26. Estimated time varying age selectivity of F21 and F22 for Step 3. Only selectivities from age-1 through age-5 are estimated. Selectivity is non sex-specific.

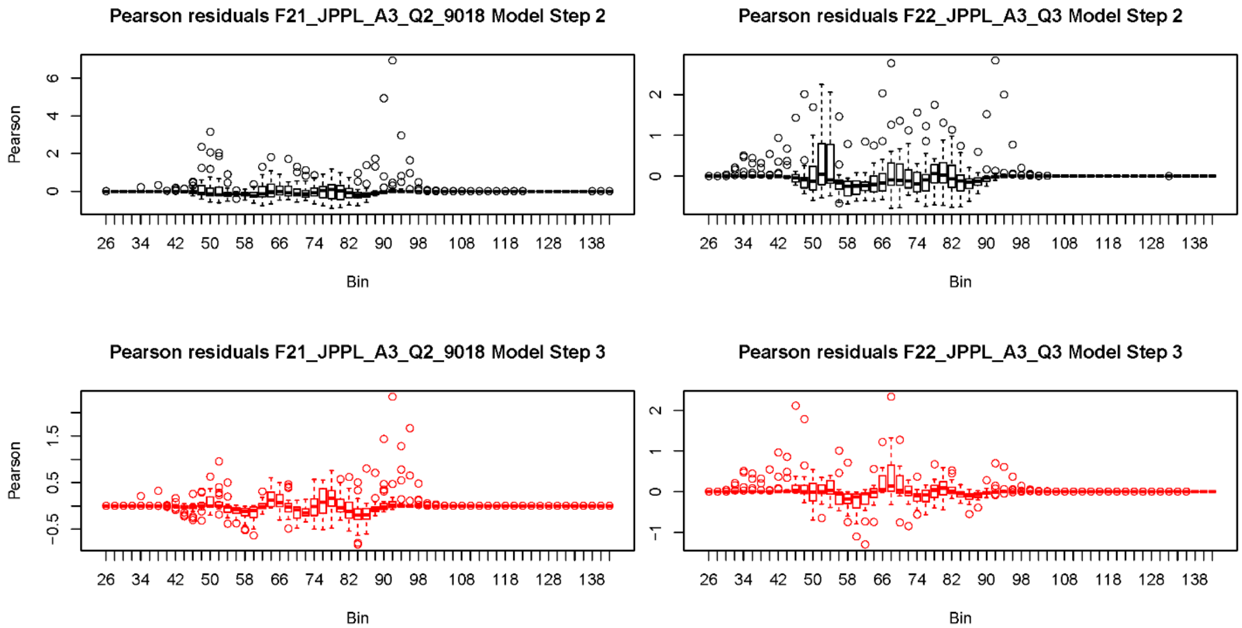

Figure 27. Pearson residual boxplots of the size composition data for F21 and F22, with (Step 3; red) and without (Step 2; black) annually varying selectivity. Smaller values indicate better model fit.

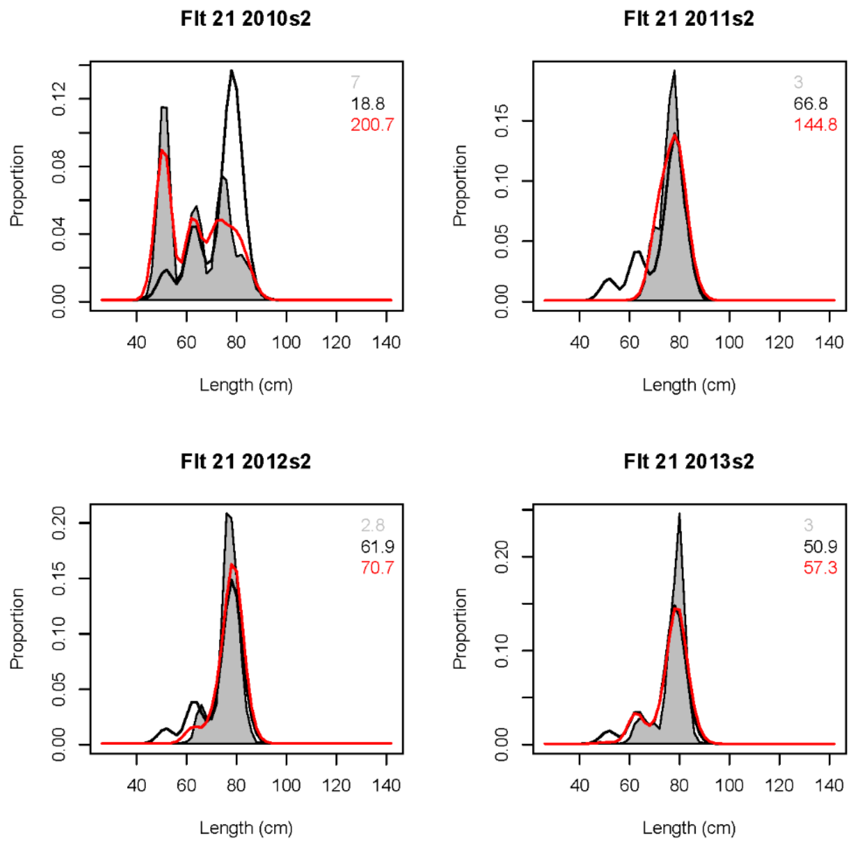

Figure 28. Example of model fits to F21, with (Step 3; red) and without (Step 2; black) annually varying selectivity. Numbers indicate input (grey) and model effective (Step 2 – black; Step 3 – red) sample size.

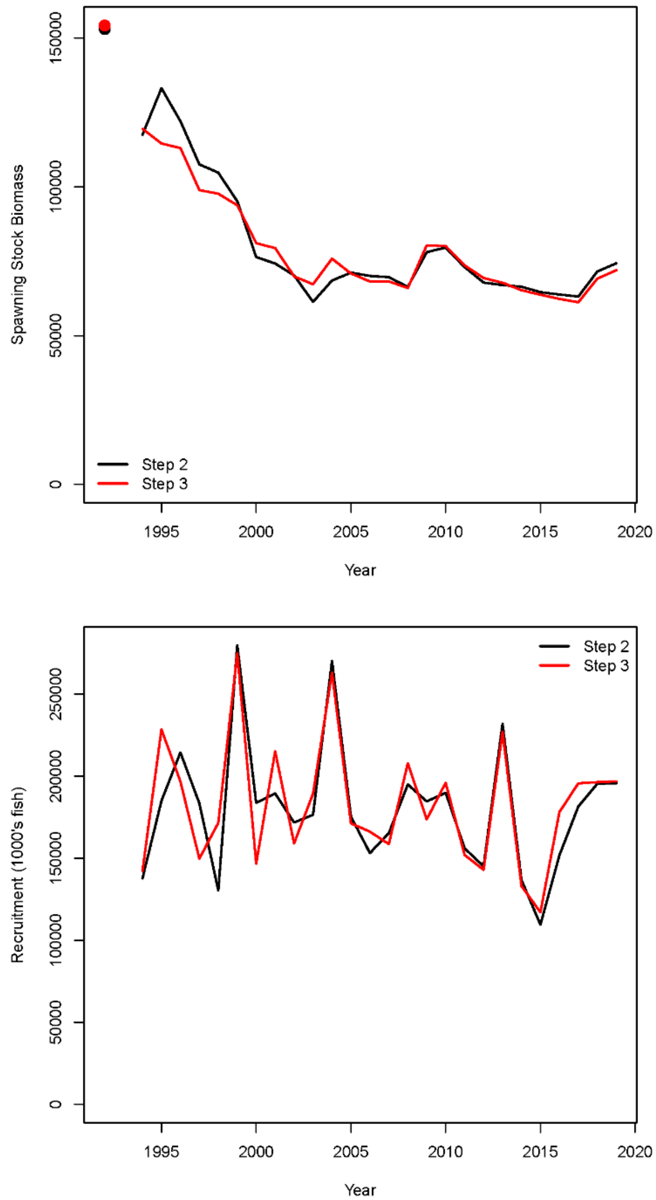

Figure 29. Comparison of estimated female SSB (upper) and recruitment (lower) between a model with (Step 3; red) and without (Step 2; black) annually varying selectivity for F21 and F22.

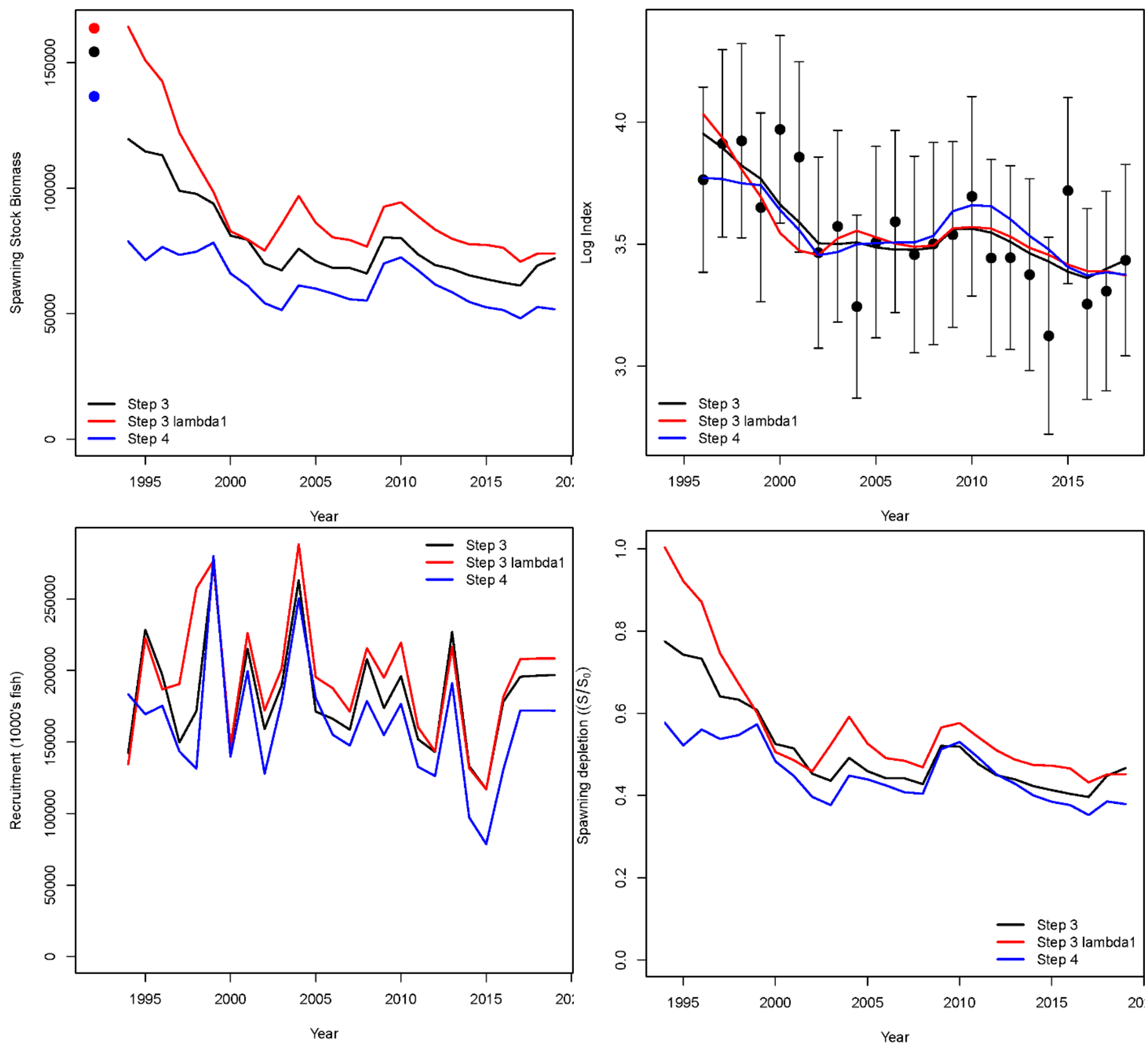

Figure 30. Comparison of estimated female SSB (upper left), fit to adult index (upper right), recruitment (lower left), and spawning depletion (lower right) between the Step 3 model (black), the Step 3 model with size composition lambdas at 1 (red; Step 3b) and a model with alternative initial weighting (blue; Step 4).

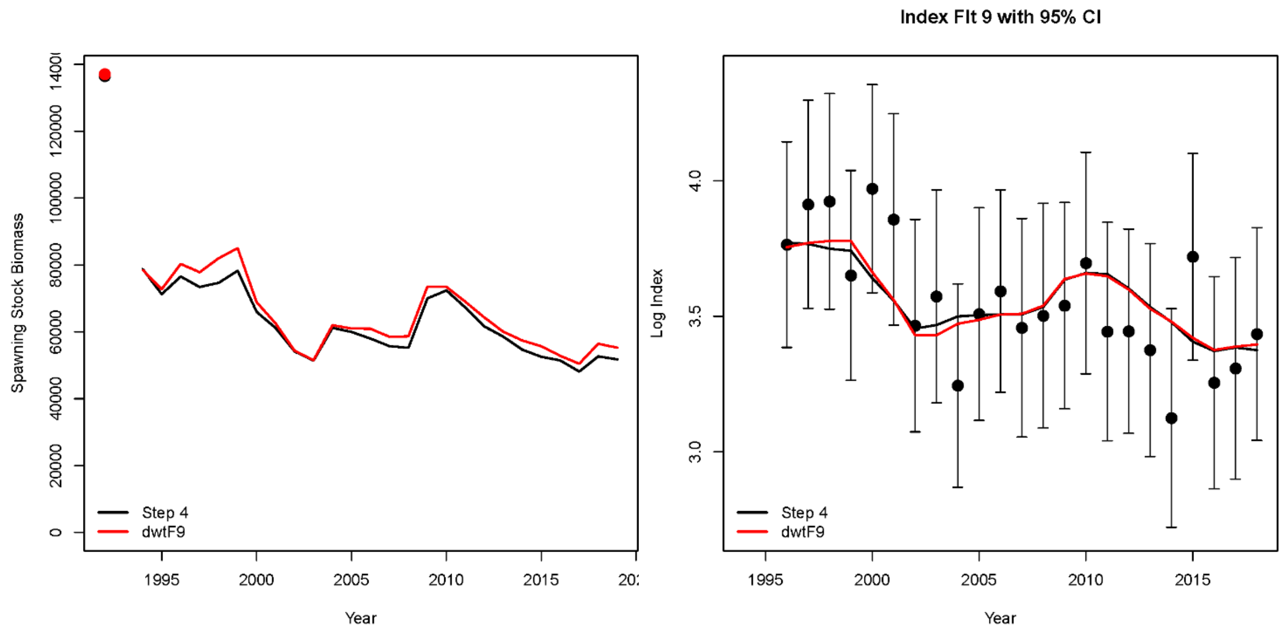

Figure 31. Comparison of estimated female SSB (left panel), and fit to adult index (right panel) between the Step 4 model (black), and a model with downweighted size compositions of F9 (red).

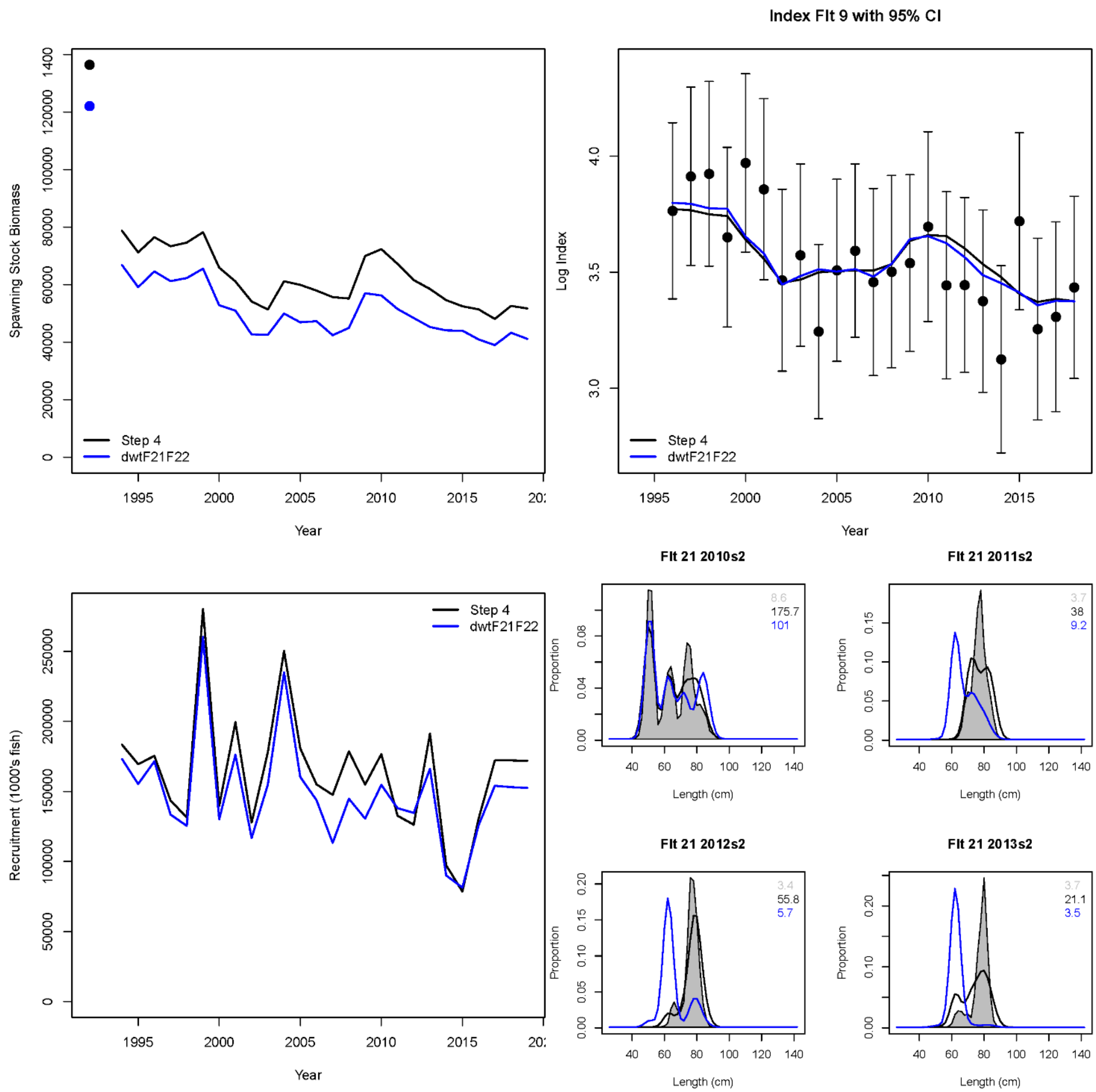

Figure 32. Comparison of estimated female SSB (upper left), fit to adult index (upper right), recruitment (lower left), and fit to a selection of size composition data (lower right) between the Step 4 model (black), and a model with downweighted size compositions of F21 and F22 (blue).

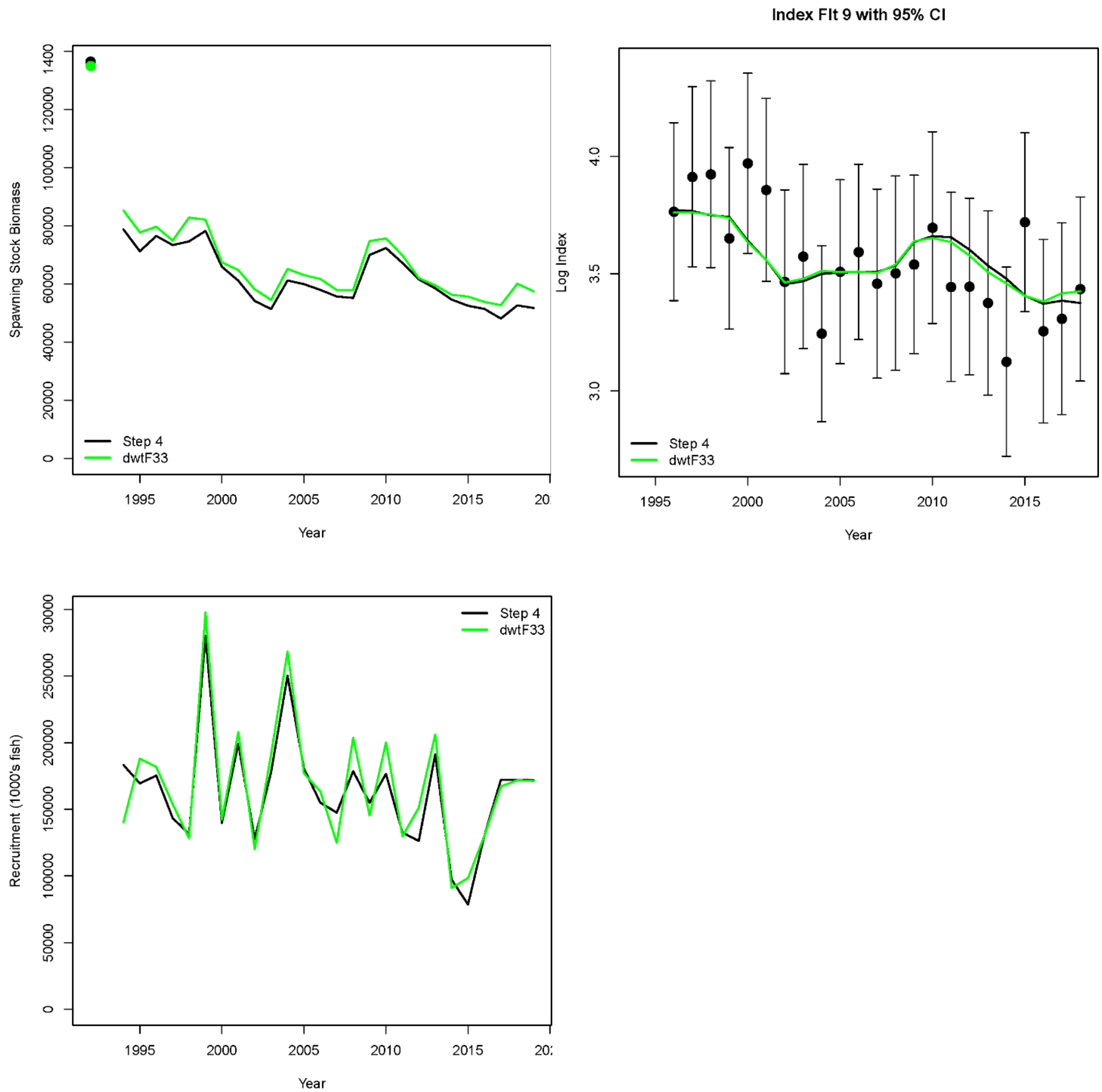

Figure 33. Comparison of estimated female SSB (upper left), fit to adult index (upper right), recruitment (lower left) between the Step 4 model (black), and a model with downweighted size compositions of F33 (green).

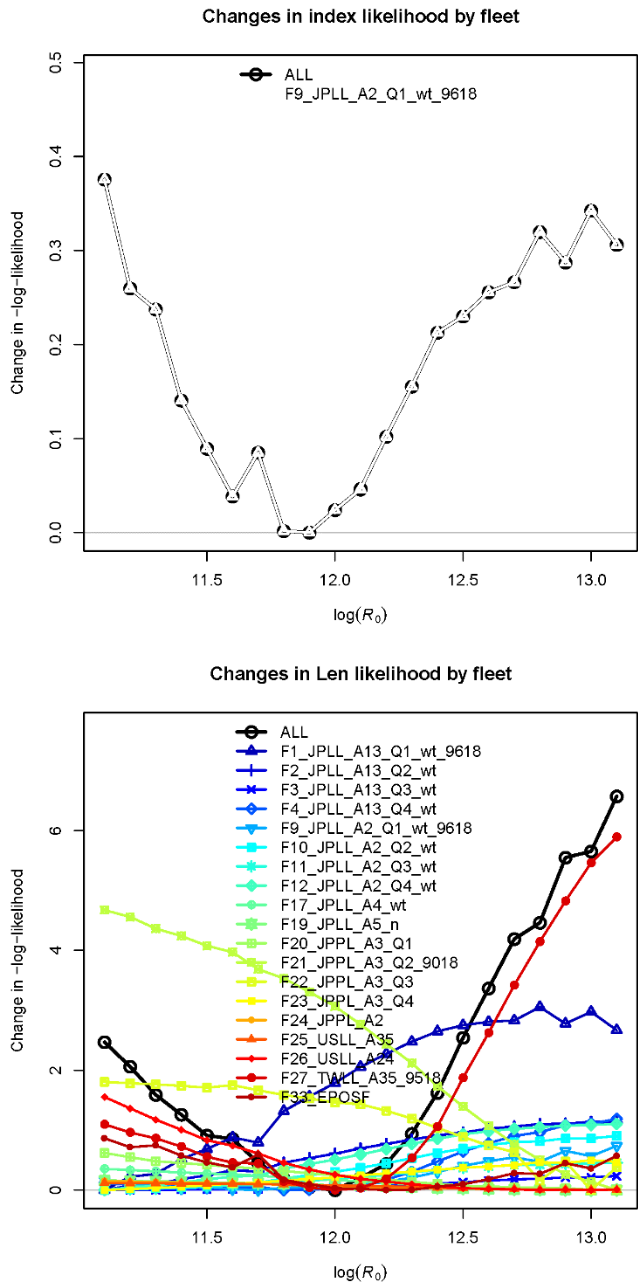

Figure 34. R0 profile of the Step 4 model for the adult abundance index (upper) and fishery specific components of size composition data (lower). Occasional jaggedness of the profile is likely from some selectivity parameters of some models being stuck on bounds but do not detract from the general shape of the profiles.

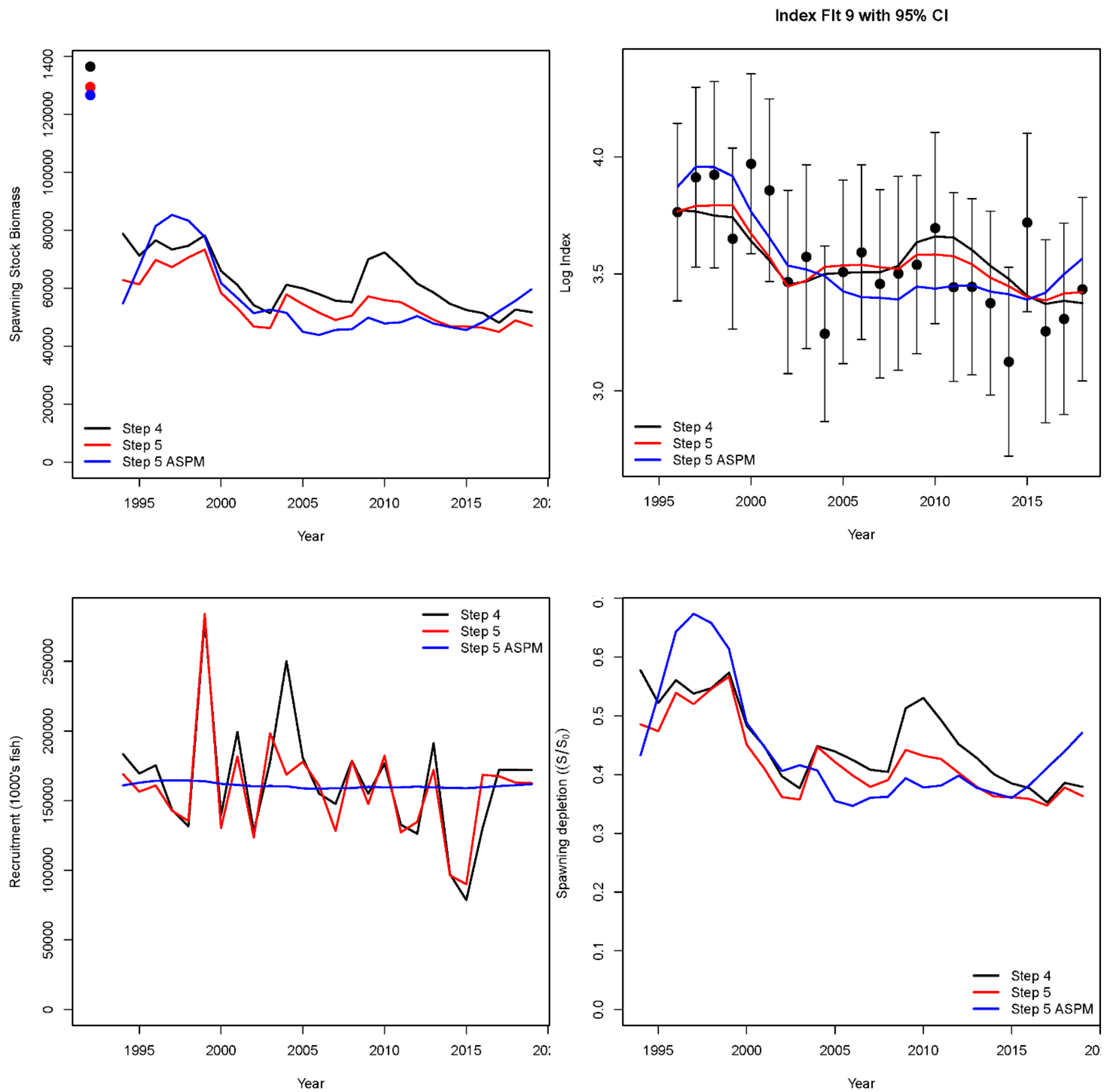

Figure 35. Comparison of estimated female SSB (upper left), fit to adult index (upper right), recruitment (lower left), and spawning depletion (lower right) between the Step 4 model (black), the Step 5 model (red), and the Step 5 model modified into an age-structured production model (ASPM) (blue).