Preliminary Population Dynamics Model for the 2016 Stock Assessment of Pacific Bluefin Tuna

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Abstract

This document focused the method to estimate the seasonal growth parameters using the stock assessment model as well as the setting of selectivity parameters in each Fleet. The seasonal growth, which was estimated using stock assessment model, showed rapid growth between beginnings of season 1 to ends of season 2, and slow growth between beginnings of season 3 to ends of season 4. The preliminary assessment model generally showed that the model could fit to the most of the data sources well. A Fit to the CPUEs are generally improved from the last stock assessment while some misfits are still observable (i.e. latest two years of the Taiwanese longline CPUE). The preliminary results generally show that the trend of SSB is similar with that of the last stock assessment. The highest SSB occurred in early 1960's and the second highest peak was in the mid-1990's. After that, the SSB is continuously declined until around 2010 and the SSB are leveling off thereafter. The recruitments were largely fluctuated throughout the estimation period.

1 Introduction

The last full stock assessment for the Pacific bluefin tuna (hereafter PBF) was carried out in 2012 (ISC PBFWG, 2012), and the fishery data from 2011 to 2013 were updated in Feb. 2014 stock assessment (ISC PBFWG, 2014). In the both assessments, the WG acknowledged that the assessment model was unable to reconcile the all key data sources while it represents the general conclusions about the status of stock. The sensitivity runs which were analyzed during the stock assessment workshops in 2012 & 2014 and some additional analysis suggested that there were several issues associated with the data conflicts among the abundance indices (Catch Per Unit Effort; CPUEs) and size composition data sets, and the possible misspecification of growth assumption (ISC PBFWG, 2012; 2014; IATTC, 2014; Kumegai et al., 2015; Fukuda et al., 2015).

After 2014 PBF stock assessment, a lot of works have been done for the CPUE standardization methods (Hiraoka et al., 2015a; Kanaiwa et al., 2015; Sakai et al., 2016a; Chang and Liu, 2016), size composition estimation methods (Hiraoka et al., 2015b; 2015c; Sakai et al., 2015a; 2015b; Kim et al., 2015; Fukuda et al., 2015; Nishikawa et al., 2015, Dreyfus Leon & Aires-da Silva, 2015), growth estimation (Shimose and Ishihara 2015), and modeling (Oshima & Fukuda 2015, Lee et al., 2015) to overcome the above mentioned issues and possible issues in the future. PBFWG carefully discussed those works and related works at the previous two workshops and acknowledged that those works would contribute to the improvements of input data and modeling work of 2016 stock assessment.

With those improvements, it is expected that the new stock assessment model is able to make better fits to the reliable input data sources without requiring excessive data weighting measures. In this document, we provide preliminary analysis of modeling using the Stock Synthesis (SS) 3.24f (Methot & Wetzel, 2013) to achieve the adequate model's fits to the all of important data sources as well as the traits of the growth of this species.

2 Materials and Methods

2.1 Basic model configuration

The model is implemented using SS Version 3.24f. The model assumes a single well-mixed stock for PBF and does not consider a spatially explicated structure. All the catch and size composition data are temporally stratified into the following 4 quarters of July-September, October-December, January-March, and April-June. Those quarters (Jul-Sept, Oct-Dec, Jan-Mar, and Apr-Jun) are assigned to 1st, 2nd, 3rd, and 4th seasons, respectively as the fishing year of PBF. The time period modeled in this assessment is 1952-2014 including the updated recent two years (2013-2014).

2.2 Data

The data for this model is the SS data file which was shared among the WG members at 16th January 2016 that includes the updated Japanese and Taiwanese longline CPUEs as well as all the other matters adopted by the WG at November 2015 meeting. The detailed information of this SS data file especially about the catch, CPUE, and size composition is described in Sakai et al. (2016b). All the CPUE time series which was agreed to use in the WG were fitted in the model.

2.3 Fleet definition

A preliminary model run using prototype assessment model indicated that the size composition of some fleets showed a seasonal pattern. The aggregated size composition of Fleet 2 within season showed two modes in season 2 (October to December), while there were only single mode in the other seasons (Fig. 1). These 2 modes in season 2 were considered to be age 0 and 1 PBF, respectively, which were born in early summer of each year and a previous year. We assumed that there might be a different local availability between the season 2 and the rest of the seasons in the fishing ground of this fishery (East China Sea) due to the nature of their migration (Kitagawa et al., 2002) or traits of schooling behavior. To estimate their selectivity patterns adequately, we separated Fleet 2 into two fleets by season; new Fleets 2 (season 1, 3, and 4) and Fleet 17 (season 2) (Table 1).

In season 1 of Fleet 6 (Japanese troll fishery) catches mainly PBF at 2 or 3 months-old, which corresponds 20-30 cm of the fish length. Age-0 PBF showed strong seasonal growth and grow fast at summer season (Fukuda et al., 2015), as a result, the average length of the composition in the season 2-4 are much larger than that of season 1. This seasonal pattern in the troll composition data are likely due to the seasonal growth of age 0 PBF, however, our preliminary analysis could not achieve reasonable fit to this data by adding the seasonal process in the growth pattern (Fig. 2). Then, we prepared a new fleet for Japanese troll fishery in season 1 (Fleet 18). The Japanese troll for faming (Fleet 16) catch fish at the same growth stage fish, but the numbers of fish caught are not available in Fleet 18, where it is available in Fleet 16. Thus, we estimated the number of fish caught by fitting the model to the composition data of Fleet 18. It should be noted that this approach was not the best way since the selectivity of Fleet 6 is shared by the Survey 5 (Japanese troll CPUE) while the troll CPUE was estimated and standardized based on the whole year data. Thus, to separate the composition data of Fleet 6 seasonally might affect (or give some bias) to the selectivity of the troll CPUE.

2.4 Selectivity

Estimation of the selectivity patterns of each fleet was summarized in Table 1. It should be noted that we assumed length-based dome shape selectivity to the all fleets except fleet 12 (Taiwanese longline) which was assumed asymptotic selectivity as the last stock assessment and Fleet 16 which was assumed age-based selectivity. In the preliminary analysis, we confirmed that neither of the length-based more flexible selectivity (Cubic spline) nor non-parametric age-based selectivity options showed much better fits to the complex size composition data (Japanese Set-Net fleet) whereas those options required estimation of much larger number of parameters (Iwata & Fukuda, 2016). The asymptotic selectivity was assumed for the Taiwanese longline fleet (Fleet 12) as it caught the largest size range of PBF.

For the Fleet 1 (Japanese longline fleet), different selectivity were assumed before and after 1993 in accordance with the period of CPUE series. We estimated 5 of 6 parameters of the selectivity except for that of the selectivity of first bins for each time period. The selectivity for the largest bin is also estimated since this fishery also caught very large PBF.

For Fleets 2 and 3 (Japanese pelagic purse seine and Korean offshore large purse seine), a single constant selectivity for both fleets were assumed since these fishery showed similar size composition data through the data period.

Fleet 4 (Japanese tuna purse seine in the Sea of Japan) showed characteristic composition that this fleet seemed to utilize a dominant cohort over 5-6 years until 2002, and they utilized relatively small fish (mainly around 110-160 cm) after 2002. The catch amount of this fleet increased after 2003 and is one of the biggest fleets which catches PBF spawner currently. Time period from the 1980's to early 2000's might be a dawning age for this fishery and their operation might not be the same with the current style. Fukuda et al. (2012) suggested that the difference in the size composition would be affected by the fishing operation (fishing month and fishing ground). In addition to the fishing operation, the migration of PBF as well as local/whole age structure (availability at age) would also affect the size composition data. Since the large effort were paid for the size sampling of this fishery (Fukuda et al., 2012), and the WG recognized the quality of composition data of this fleet is very good (PBFWG, 2012). Here, we assumed the several different selectivity patterns depending on the time period for Fleet 4.

For Fleet 5 (Japanese tuna purse seine of the Pacific Ocean side), the WG agreed to use the same period of composition data with the last assessment, although the WG hoped to see a longer time series of better quality data for this Fleet in the future assessment. We assumed a few selectivity patterns to correspond the specific year's composition data which showed a peak in smaller size of PBF (i.e. 2004-2005).

Japanese troll (Fleet 6) is the one which caught mainly age 0 PBF throughout data period. Since the selectivity of this fleet was also used by the CPUE, we assumed constant selectivity.

Fleet 8 and 9 (Japanese Set Net seasons 1 to 3, and 4) caught age classes from mainly 0 to 5, and composition data showed different and complex patterns depending on the year and season. A reason for the separation of Fleet 8 and 9 by the season was that there were a tendency that large PBF appear in the season 4. We did not choose a method to combine those two fleets and estimate a length/time flexible selectivity (i.e. combination of time varying selectivity and non-parametric age selectivity). We have two reasons not to use this option. First one is that the time varying selectivity only cannot correspond to the seasonal difference of the size composition by itself. It might be required combination of super season option and time varying selectivity. Second reason is that 'simple fleet-flexible selectivity' option required the large number of parameters and we recognized that the data quality of those fleet are fair to good (PBFWG, 2014). Thus, we considered it better not to estimate so many parameters for those fleets to avoid a possible risk of overfitting. Instead, we estimated several time varying selectivity patterns for both of these fleets, separately.

Fleets 10 and 11 are the fisheries which operated in the North part of Japan (Hokkaido & Aomori). Those fleets have good 'weight composition' based on their sales slip data due to the nature of those fisheries (PBFWG, 2014). Main components of fisheries are consisted by set net (Fleet 10), handline and small-scale longline (Fleet 11), and combined weight composition of those fleets seemed to have a relatively consistent trend in terms of its distribution. Thus we combined those two fleets and estimated several time varying selectivity patterns.

Fleets 13 and 14 had been considered basically same fisheries as an 'EPO commercial purse seiner' which operated off the coast of southwestern U.S. and Baja California. The main fishing seasons extended in season 4 (April to June) and season 1 (July to September) of next fishing year. The EPO purse seine of U.S. dominant period was one of the biggest fishing fleets at that time period (1952-1982) and there were some quarters which have large input sample size (i.e. 50 in 1963). Our preliminary analysis suggested that the misfit to those quarters negatively affected to the fit to the CPUE of corresponding time period (Survey 2 or Survey 3). EPO purse seine fleet when the Mexican aquaculture was fully developed (after 2001) was one of the biggest fishing fleets currently. We assumed several time varying selectivity patterns to both of Fleet 13 and 14 separately.

EPO sports fishing fleet (Fleet 15) referred to the selectivity of EPO commercial purse seiner of U.S. dominant period (1952-1982). Japanese troll fleet which caught fish for the seedlings of aquaculture (Fleet 16) is one of the fleets which has the catch amount information in a unit of number of fish. As this fleet caught age-0 fish only, full selectivity for age 0 was assumed. For Fleet 17 (Japanese small pelagic purse seine fleet season 2), we assumed a few time varying selectivity patterns for some years when smaller fish than the rest of the period were caught. For Fleet 18 (Japanese troll for farming), we assumed constant selectivity throughout the assessment period.

2.5 Growth

In the Nov. 2015 meeting, the WG agreed to consider adding the seasonal growth process in the assessment model. In here, we provided 4 options of growth model. The first one is a standard von Bertalanffy growth function as used in the previous assessment (vB model). The parameters were estimated based on reading otolith samples from 2010 fish (Fukuda et al., 2015). The second option is also standard von Bertalanffy but set a parameter A1 to a positive value to mimic the 2 stanza growth form (vB-2stanza model). The third option is prepared to represent the different two birthday groups which were indicated to show different growth pattern by the direct observation of otolith daily rings (Fukuda et al., 2015) (vB-2stanza-2GP model). The fourth option is the seasonal growth. We estimated the seasonal growth parameters internally by the SS (seasonality in the parameter K) in a preliminary run, and fixed those parameters in the final run for the stock assessment.

To estimate the seasonal growth rate and other growth parameters (Length at Amin, Length at Amax, von-Bertalanffy K, CV of young, CV of old), we prepared 'Conditional age at length data' to introduce in the assessment model. These data were the same data set as described in Fukuda et al. (2015) from 2010 individual PBF. Configuration of the SS model was almost the same as the prototype model shared among the WG in 16th Jan 2016. Only the difference was the introduction of 1 cm of population length bin (1cm bins from 10cm to 296cm). The lambda of the age observation data was set as 3.0 to enable the stable estimation of the growth parameters.

3 Results

3.1 Growth

The growth curves estimated by each model were shown in Figure 3. vB-2stanza model and vB-2stanza-2GP model showed smaller length at age 0 than the vB model. Between age 0.25 to 3.0, average length of vB-2stanza model and vB-2stanza-2GP model were larger than vB model, while the differences were small after age 3. The seasonal growth model showed rapid growth between beginnings of season 1 to ends of season 2, and slow growth between beginnings of season 3 to ends of season 4. The average length of seasonal model at beginnings of season 1 and 4 were smaller than those of the vB model, while average length of the seasonal model at beginnings of season 2 and 3 were larger than those of the vB model. Observed and estimated age compositions for a preliminary model run to estimate the seasonal growth parameters were shown in Figure 4.

Among those model runs which have the difference in the growth curve, seasonal model showed the smallest total negative log likelihood (Fig. 5). Especially, seasonal model showed better fits to the length compositions of the fleets which caught the young PBF (Fleet 2, 6, 13, and 14). Fits to the CPUE data are better in the vB model than the rest of the models.

3.2 Model results

Here, we show the results of the vB model and the seasonal model. In general, both of the models fitted well to the input data. Fit to the CPUEs are generally good except the latest two years of the Taiwanese longline CPUE (Fleet 27 in Fig. 6) in the both models. Fit to the troll CPUE (Fleet 23 in Fig. 6) showed some difference while both models fitted well to the data. As an indices of the goodness of fit, Root Mean Square Error (R.M.S.E.) were shown in Table ##. Fit to the composition data were also good in Fleet 1 , 2 , 4, 6, 10, 12, 13, 14, 17 and 18 (Fig. 7). Although fits to the composition in Fleet 5, 8, and 9 were not very good, general distributions of each Fleet are represented.

The jitter analysis show that the model likely converges to a global minimum, with no evidence of further improvements to the total likelihood. The model fits to the important abundance indices do not show any substantial difference by the random perturbations of initial values (Fig. 8). The model hessian is positive-definite and the variance-covariance estimated.

The preliminary model results generally show that the trend of SSB is similar with that of the last stock assessment. The highest SSB occurred in early 1960's and the second highest peak was in the mid-1990's. After that, the SSB is continuously declined until around 2010 and the SSB are leveling off until 2014. The recruitments were largely fluctuated throughout the estimation period, and the average recruitment of most recent 4 years (2011-2014) is lower than the historical average.

4 General Conclusion

Here, we presented preliminary model run and its results to achieve the adequate model's fits to the all of important data sources. Model fits were generally well in the result presented here as well as under the other modeling assumptions such as the much more time varying selection, non-parametric age selection, or a same selectivity across a set of neibouring quarters of different year (data super period).

Although the model was able to fit to the data well which seems to have very high reliability, we still have some room left for further improvement in some composition data and the adult abundance indices. However, some of the input data requires us to be careful to handle it because there seems to be some less reliable data. Adding the further process to the model to reduce the residuals is one of the way and the other way would be the re-weighting to reduce the effect of the misfit only if it is critical effect.

Table 1. Configuration of the Fleet definition, relative weighting by lambda, and selectivity

Fleet #	Fisheries	Size bin definition	Selectivity Estimates	Size data lambda	Compdata_input sample size	Time Varying Selectivity
Fleet1	JLL	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Scaled Number of fish measured	Y
Fleet2	JSPPS & KOLPS	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Number of landing well measured	N
Fleet3	KOLPS	Length bin	Mirror Fleet 2	0		-
Fleet4	TPSJS	Length bin	Double normal Length selectivity(Size SELEX-24)	1	same velue with the last assessment	Y
Fleet5	TPSPO	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Number of landing well measured	Y
Fleet6	Troll	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Total month of well sampled port	N
Fleet7	PL	Length bin	Mirror Fleet 6	0		-
Fleet8	SetNet_Seas1-3	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Total month of well sampled port	Y
Fleet9	SetNet_Seas4	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Total month of well sampled port	Y
Fleet10	SetNet_HK_AM & JOthers	Weight bin	Double normal Weight selectivity(Size SELEX-24)	1	Total month of well sampled port	Y
Fleet11	JOthers	Weight bin	Mirror Fleet 10	0	Total month of well sampled port	-
Fleet12	TWLL	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Scaled Number of fish measured	N
Fleet13	USCOMM (-2001)	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Number of haul well measured	Y
Fleet14	MEXCOMM (2002-)	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Number of haul well measured	Y
Fleet15	EPOSP	Length bin	Mirror Fleet 13	0		-
Fleet16	Troll4Pen	Length bin	Fixed Age Selex-11 (Age-0=100%, >Age-0=0%)	0		-
Fleet17	JSPPS (season 2)	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Number of landing well measured	Y
Fleet18	Troll (season 1)	Length bin	Double normal Length selectivity(Size SELEX-24)	1	Total month of well sampled port	N

Table 2. Configuration of the Survey definition, relative weighting by lambda, CV, and R.M.S.E. by the two preliminary model

CPUE #	Fisheries	lambda	Mean CV	Root Mean Square Error	
				vB model	Seasonal Growth model
Survey 1	Japanese Lonline (1993-)	1	0.2	0.277	0.271
Survey 2	Japanese Lonline (1952-)	1	0.2	0.212	0.220
Survey 3	Japanese Lonline (1974-)	1	0.2	0.146	0.160
Survey 5	Japanese Troll	1	0.2	0.176	0.177
Survey 9	Taiwanese Longline	1	0.2155	0.383	0.389

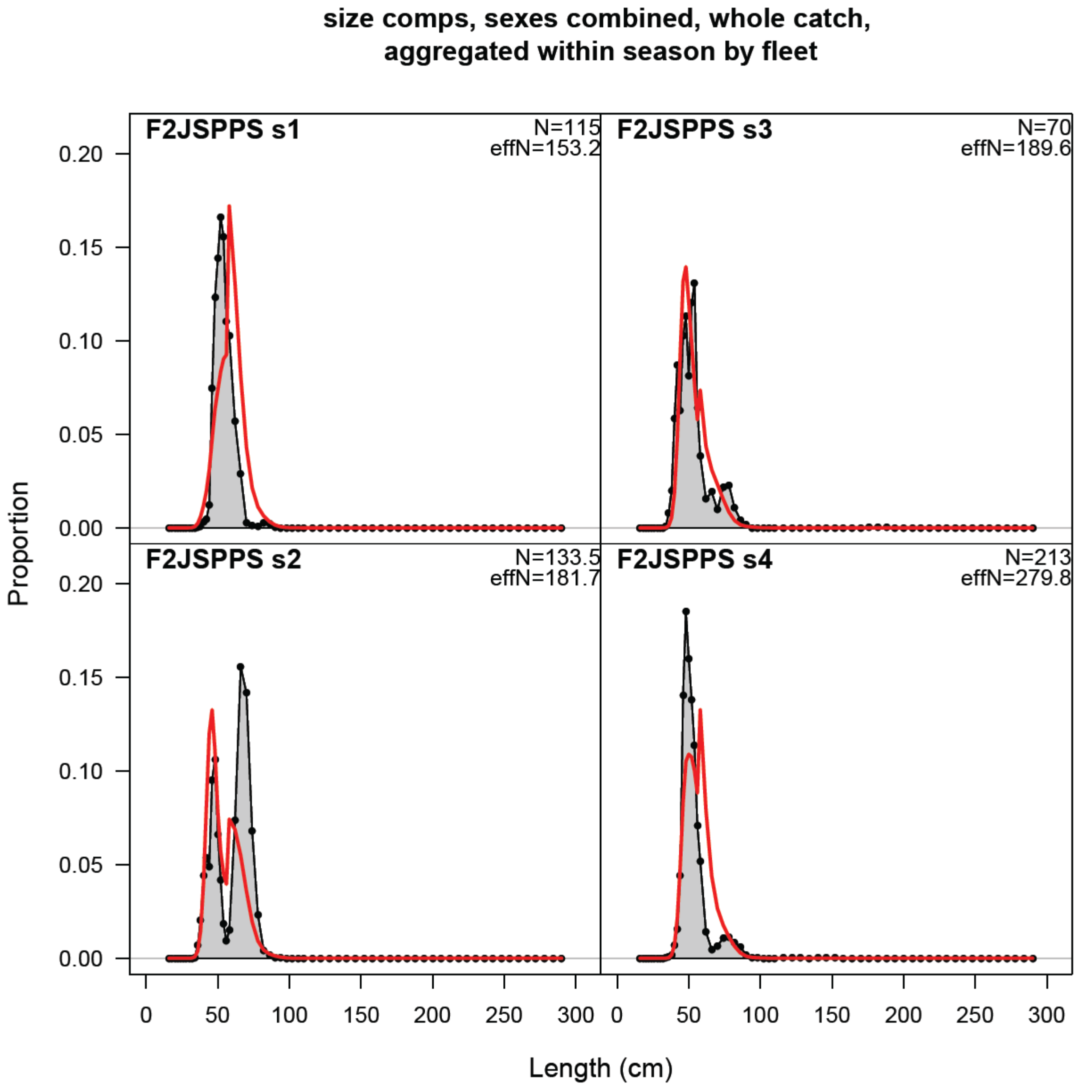

Fig. 1 Seasonally aggregated size composition of Fleet 2 in the prototype model (gray shaded area). Red line indicates a model prediction.

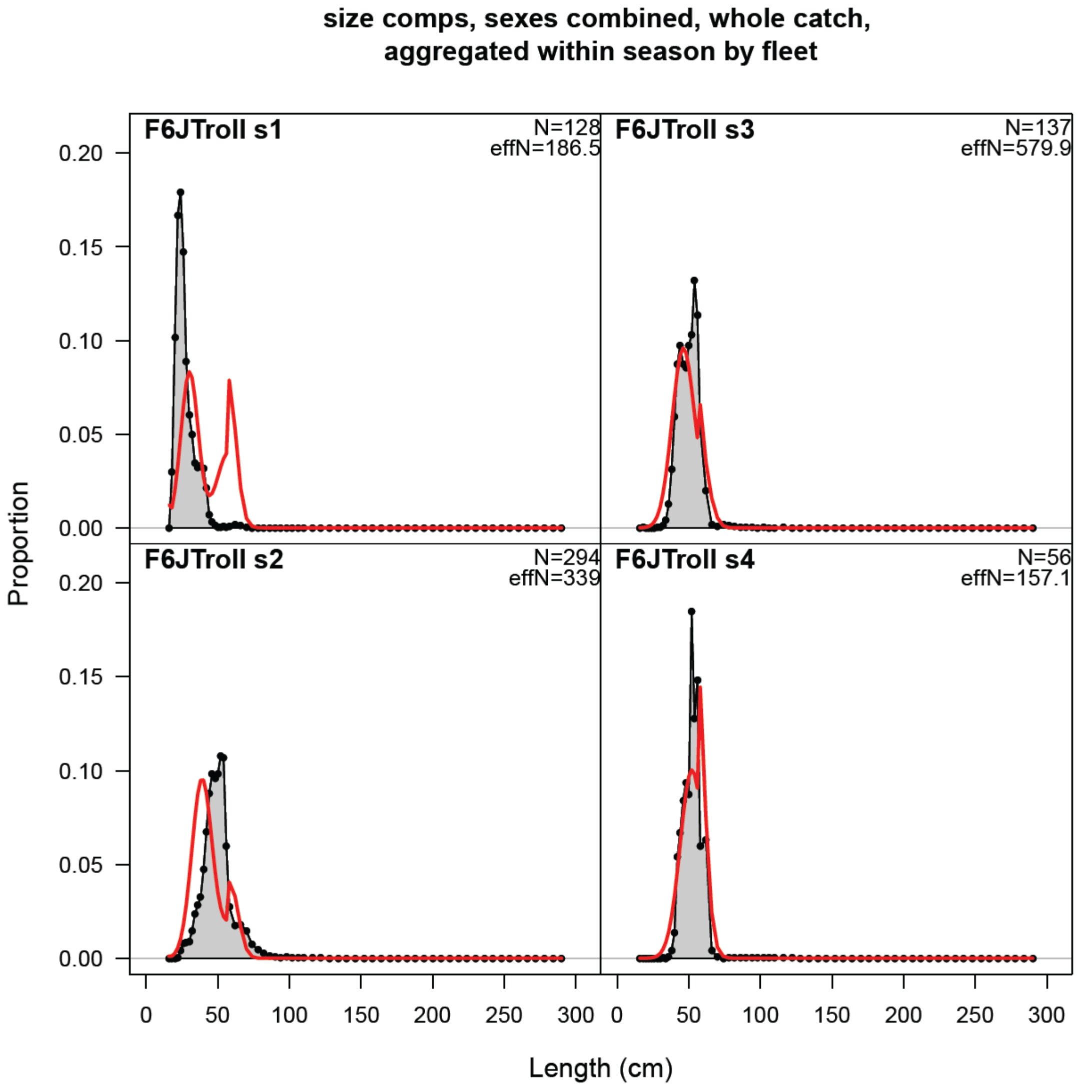

Fig. 2 Seasonally aggregated size composition of Fleet 6 in the prototype model (gray shaded area). Red line indicates a model prediction.

@ Growth curve, Spawner−recruitment and M

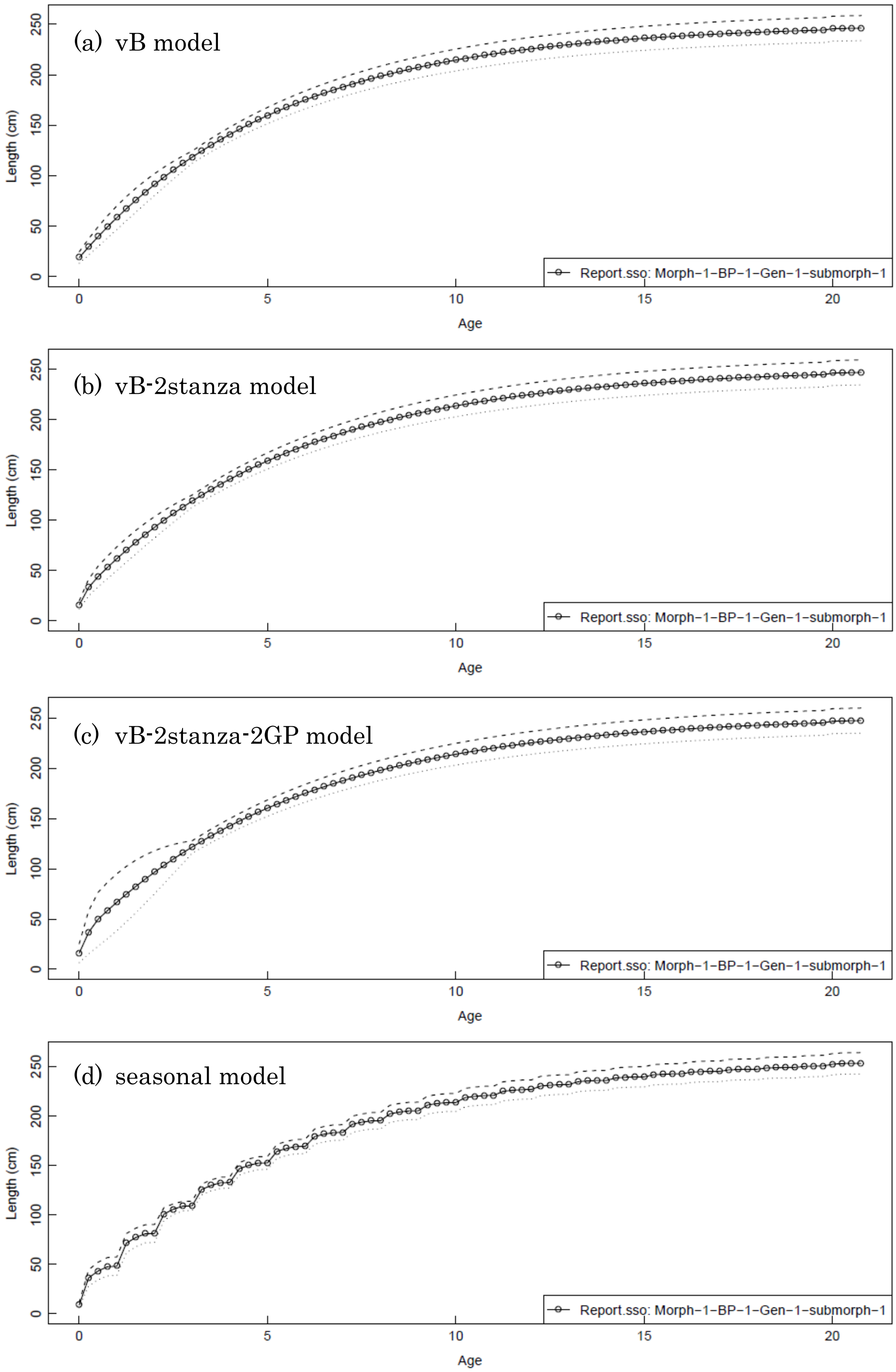

Fig. 3 Growth curves by each option.

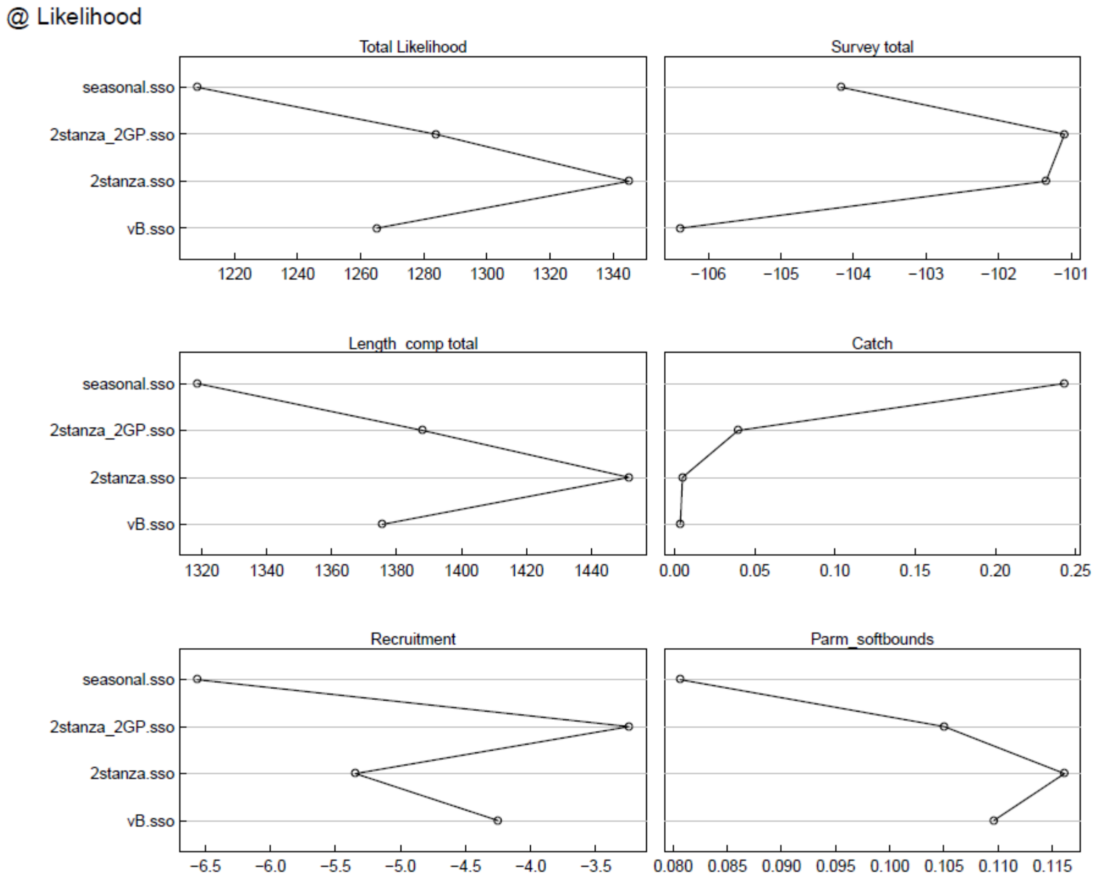

Fig. 4 Negative log likelihood by each data component in each model.

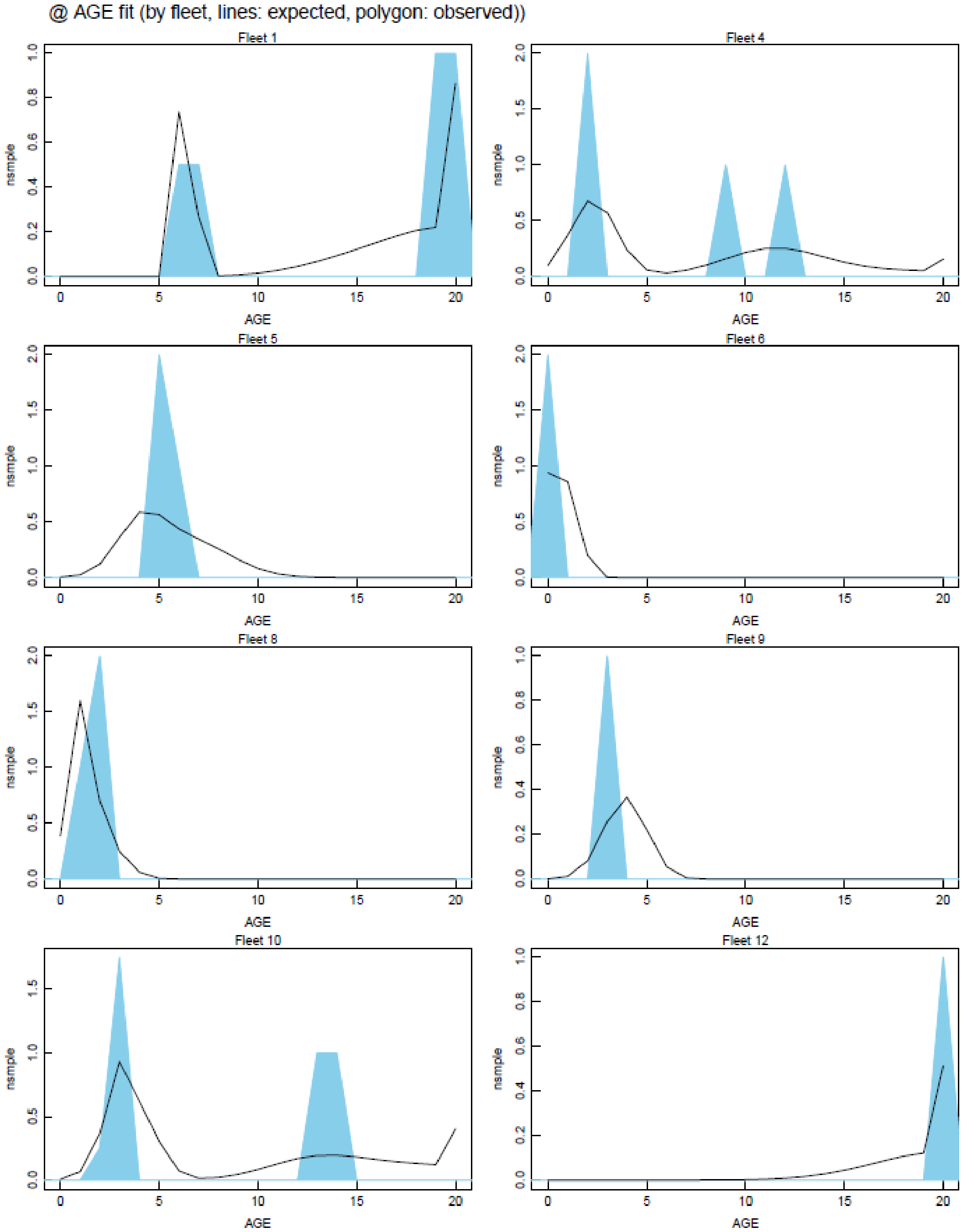

Fig. 5 Observed and estimated age compositions in each Fleet for the preliminary model run to estimate seasonal growth parameters. .

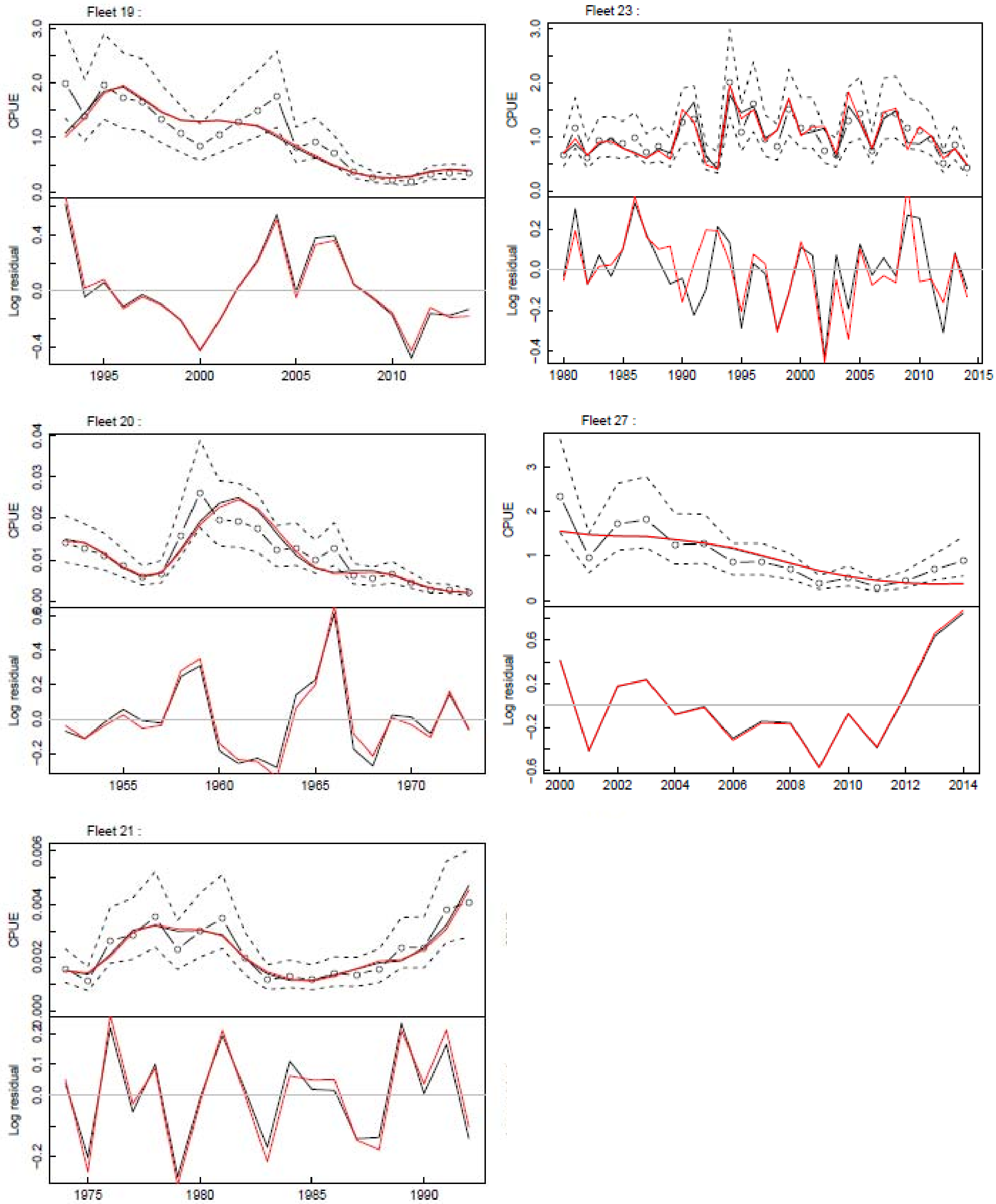

Fig. 6 Observed (line + circles) and expected (line) CPUE, and its log residuals (observed minus expected). Fleet 19: S1 terminal Japanese longline CPUE, Fleet 20: S2 Japanese Longline early period CPUE, Fleet 21: S3 Japanese Longline late period CPUE, Fleet 23: S5 Japanese troll CPUE, F27: S9 Taiwanese Longline CPUE. Black and Red lines indicated expected values by vB-model and seasonal model.

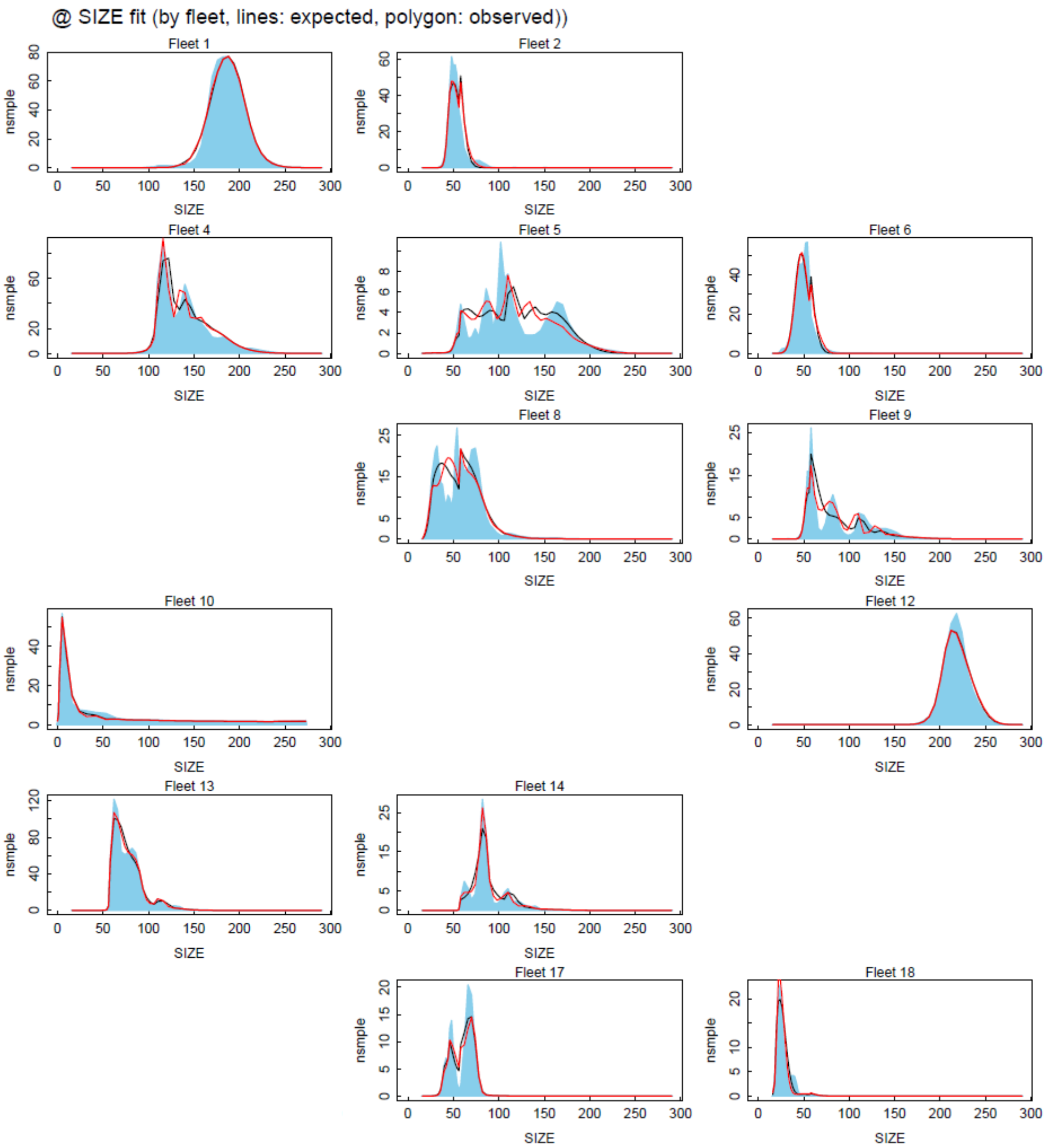

Fig. 7 Fits of predicted length (or weight) composition to the observed size composition for F1 to F18. Blue polygon indicates observed size composition. Black, red lines indicate predicted size compositions from vB model and seasonal growth model, respectively.

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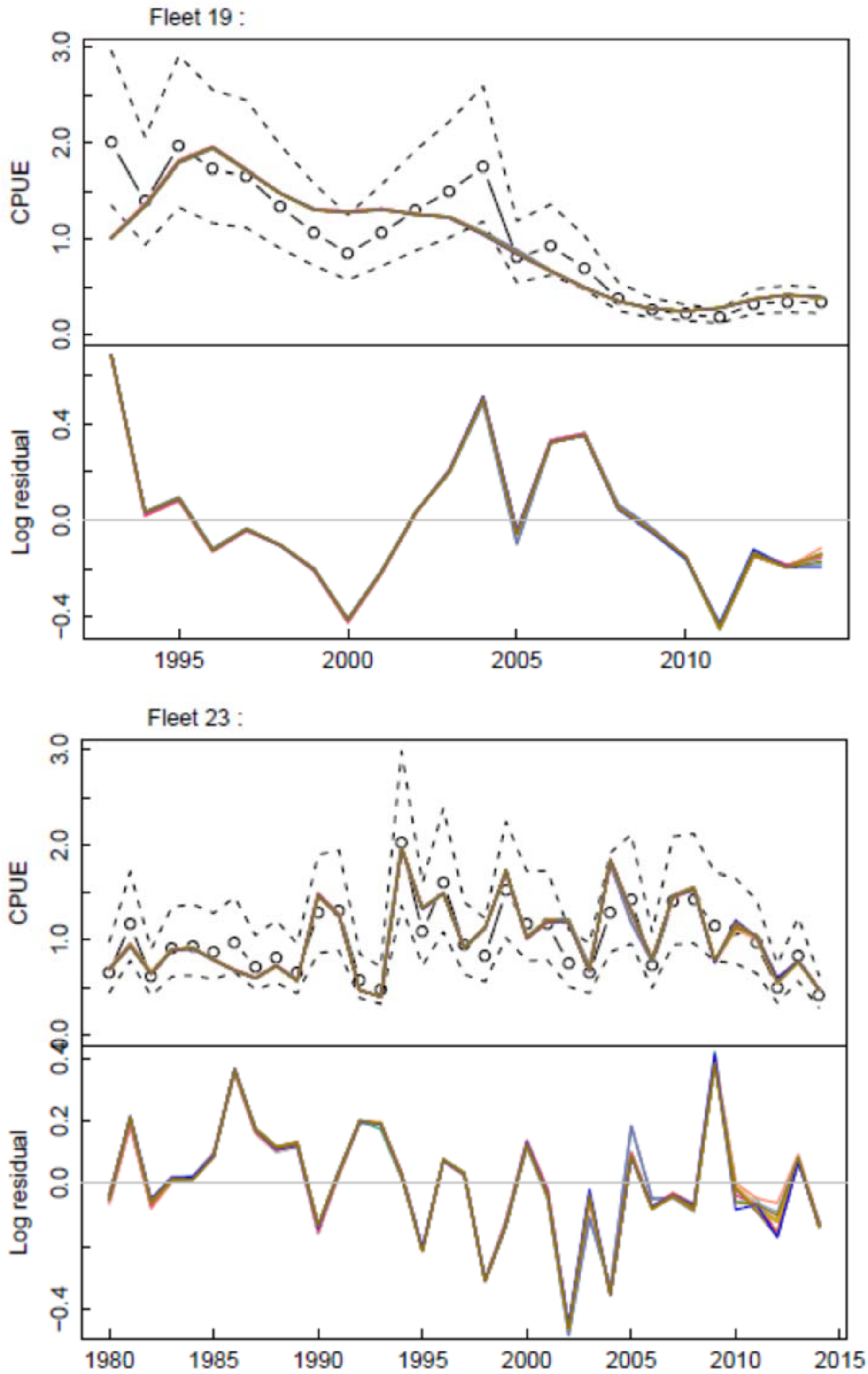

Fig. 8 The model fits to the Japanese long line CPUE (Fleet 19) and Japanese troll CPUE (Fleet 23) estimated by the Seasonal growth model. Each different colored line indicates the estimated value from different initial values (jittering).

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