A preliminary population dynamics model for the 2018 updated stock assessment of Pacific bluefin tuna

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Summary

Population dynamics model for the stock assessment of Pacific bluefin tuna was updated with the fishery data of additional 2 years until 2016 fishing year. In this document, we described the setting of the updated model and some results of the model diagnostics. Most of the parameters were estimated well by the updated model and the assessment results did not drastically change from the previous stock assessment. The retrospective diagnostics and likelihood profile over the fixed population scale parameter suggested the model kept its internal consistency among most of the sources of data and assumptions, which was confirmed in the previous stock assessment. The updated model fitted generally well to the size composition data although there were some misfits to the recent year's data. Those misfits were considered to be occurred by the unmodeled process such as variability in the migration patterns, the local availability/fishing activity, and/or the growth patterns. The model fits to the updated abundance indices were also generally well, although the root mean square error for a terminal longline index were higher than the previous assessment. The unfished SSB (SSB0) was estimated to be about 643 thousand t (R0 = 13.7 million fish) and was almost identical with the previous assessment. SSB estimates exhibited long term fluctuations, and in the most recent two years, SSB continued to show a tendency of slight increase which has been appeared since 2010. The depletion ratio (SSB/SSB0) of the terminal year (2016) corresponded 3.3%. The recruitment estimates were almost identical with the previous assessment. The recent two years (2015 and 2016) of the recruitments were lower and higher than the estimated unfished recruitment, respectively. Note that those results were derived from a preliminary model and the formal results to consider the stock status and conservation information of this species will be developed by the PBFWG.

1 Introduction

The 16th International Scientific Committee for tuna and tuna-like species in the North Pacific Ocean (ISC) plenary, held in Sapporo, Japan from 13-18 July 2016, approved the proposed assessment schedule by the Pacific Bluefin Tuna Working Group (PBFWG) which was summarized as every four years of a benchmark assessment and every second intervening year of an update assessment (ISC, 2016). With this assessment schedule, the update stock assessment using all available new catch, effort, and size data up to June 2017 (2016 fishing year; FY) was scheduled in 2018. The main purpose of this assessment is to closely track the stock status by updating the most recent data and to pay close attention to trends of recruitment, spawning stock biomass, and fishery. In principle, the catch and size composition for an update assessment would be only updated for the additional two years (2015 and 2016 FY) as well as the terminal year in the previous assessment (2014FY). As for the catch-per-unit of effort (CPUE) based abundance index, due to the nature of the CPUE standardizations method, the whole time series will need to be re-standardized with the additional 2 years data. The statistical method used to standardize CPUE (e. g. model structure, explanatory variable, and error structure) will be the same as those used in the 2016 stock assessment. The stock assessment model was updated according to this plan, and the model diagnostics were conducted. In this document, we reviewed the model setting for the updated stock assessment and demonstrate the results of the model diagnostics.

2 Model descriptions

2.1 Basic Configurations

An annual time step length based, age-structured, forward simulation population model was implemented using Stock Synthesis (SS) Version 3.24f (Methot & Wetzel, 2013). SS is composed of 3 model sub-components, (1) a data sub-component that relates observed quantities such as catch, CPUE, and size (in length or weight) composition of fish caught, (2) a statistical sub-component that quantifies the fit of model predictions to the data using a negative log-likelihood (NLL) function, and (3) a population sub-component that estimates the numbers and biomass-at-age of the population using fixed and estimated model processes such as natural mortality, recruitment, fecundity, growth, and fishery.

The model assumes a single well-mixed stock for Pacific bluefin tuna *Thunnus orientalis* (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 quarters, respectively as the fishing year of this species. The time period modeled in this assessment is 1952-2016 including the updated recent two fishing years (2015-2016). The biological and demographic assumptions have not been changed from the 2016 stock assessment as the original work plan.

Annual recruitment deviates are estimated from 1953 to 2016 as the main recruit deviations. The ending year of early deviation as well as the starting and ending years of no or full bias adjustment are chosen, based on the results of the 'SS_fitbiasramp' function of R4SS package (Taylor et al., 2013).

2.2 Input Data

The fisheries on the stock assessment model were defined as nineteen fleets and those were not changed from the last stock assessment. The catch data for recent two years were updated as written in Sakai et al. (2018). The quarterly catch data from 1952 to the second quarter of 2014 were not changed. The size composition data from 1952 to 2014 were not changed except some fleets which were provided newly available observation from 2014 to 2016. Detailed information about the updated size composition data were described in Sakai et al. (2018).

The whole CPUE time series need to be re-standardized with additional recent 2 years data. Japanese longline CPUE (S1), Japanese troll CPUE (S5), and Taiwanese longline CPUE from southern fishing ground (S9) were re-standardized and became available until 2016 (Sakai & Tsukahara, 2018, Fukuda et al., 2018, Chang et al., 2018). In addition to those CPUEs, S2 and S3 (past periods of Japanese longline CPUE) are used in this updated stock assessment as those were in the 2016 assessment. The inputs coefficient of variation (CV) for each CPUE time series are set as 0.2 to each year.

2.3 Selectivity

Fleet-specific selectivity was estimated by fitting length or weight composition data for each fleet except Fleets 3, 7, 11, and 15, whose selectivity patterns were fixed and borrowed from other fleets based on the similarity of size of fish caught of the fleet.

Since the PBF assessment model does not have a spatially explicated structure, the fleet-specific selectivity combines both of spatial availability to the fleet and physical selectivity of the fishing gear. The spatial availability of PBF to the fleet could be temporally variable due to the nature of highly migrate species and the possible environmental effect to their migration. To correspond the temporal changes shown in the size composition data due to the possible temporal variation of migration, temporal change in the fleet specific selectivity (time-varying selectivity) was assumed to insure adequate model fit to the size composition data (Lee et al., 2017). However, this method requires high number of parameters to estimate. In order to save the number of parameter estimates, only for the fleets with large catches of migratory ages, good size composition data, and no CPUE were modelled with time-varying selection (Fleets 4, 5, 13, 14, and 18). In principle, fleets taking only single or a few ages and fleets with small catches were applied time-invariant selectivity, unless those fleets changed their fishing patterns (Fleets 2, 8, 9, 10, 17, 19).

The fleets associated with the CPUEs were modeled as time-invariant or blocks of time-invariant dome-shaped (Fleet 6; Japanese troll and Fleet 1; Japanese longline) or asymptotic (Fleet 12; Taiwanese long line south) selectivity. Fleet 16 (Japanese troll for penning) was modeled as 100% selection of age-0. The forms of the selectivity in each fleet were not changed from the previous assessment. Only for the fleets assuming time-varying selectivity, the last year of the selectivity parameter estimates was extended to the terminal year. It should be noted that a size selectivity parameter of Fleet 13 in 1956, which was fixed at a given value in the previous assessment to avoid hitting to the lower boundary of the range of parameter estimates, was estimated since this parameter was estimable without hitting to the boundary given the current data and model structure.

2.4 Weighting of data

Weights given to catch data were S.E.=0.1 (in log space) for all fleets, which can be considered as relatively good precision to catches. Weights given to the CPUE series were assumed to be CV=0.2 across years. The weights given to fleet-specific quarterly size composition data were done on a relatively ad hoc basis, and might be subjective decisions about the quality of measurements. Sample sizes were generally low (<15 N) and were set based on the number of well-measured samplings from the number of hauls or daily/monthly landings (ISC, 2016b) except for the longline fleets. For longline fleets, because only the number of fish measured were available (number of trips or landings measured were not available), sample size was scaled relative to the average sample size and standard deviation of sample size of the all other fisheries based on the number of fish sampled.

3 MODEL DIAGNOSTICS

3.1 Likelihood profile over fixed log(R0)

Results of the profile of total and component likelihoods over fixed log(R0) for the updated model are shown in table 1. Strong influence to the global scaling of log(R0) were shown in the recruitment penalty (low side), size compositions (both low and high side), and abundance indices (high side); however, catch component did not have much impact on log(R0). The smallest values of log(R0) for recruitment penalty, all combined CPUEs component, and all combined size composition were 9.60, 9.50, and 9.50, respectively. The recruitment penalty strongly influenced to the low side, but the relative likelihood value at the fixed log(R0) of 9.55 and above were less than 1. In general, the updated model resulted in an internally consistent model regarding population scale, demonstrated by relative likelihood values for composition component < 2 units and those for index component < 1 unit at the log(R0) when estimated (log(R0) = 9.52).

3.2 Retrospective analysis

The retrospective analyses showed no substantial pattern of overestimating or underestimating SSB for recent 3 terminal years, although those of recent 4-9 years tended to be slightly underestimating (Fig. 1 upper).

The retrospective analyses showed consistent estimates of the recruitment after 1993 when the size composition data became available for the most of fleets. This analysis did not indicate substantial pattern of over- or under estimating recruitment for the recent 9 terminal years (Fig. 1 bottom).

3.3 Goodness-of-fit to abundance index

The model fits (how model predictions match to the observed data) to the CPUE based abundance indices from S2, 3, 5, and 9 (Japanese longline early and middle periods, Japanese Troll, and Taiwanese longline) were well as those for previous assessment. In particular, the base-case model fit very well to the S2, S3, and S5 (Japanese troll) indices; the root-mean-squared-error (RMSE) between observed and predicted abundance indices for these indices were close to or less than 0.2, which was the input CVs for these indices (Table 2). The model also fit well to the terminal Japanese longline (S1) index, although the RMSE was slightly higher than that of the previous assessment (RMSE = 0.3).

3.4 Goodness-of-fit to Size Compositions

The model fits the size modes in data aggregated by fishery and season fairly well given the estimated effective sample sizes (effN). The average effNs were larger than the average input sample sizes in the all fleets (Table 3), and the ratios of those two numbers were similar with those in the 2016 assessment.

However, the model could not predict some of the updated observation data (e.g. Fleet 1, 2, and 6). Those misfits to the size composition data may be due to un-modelling migration patterns, variability in the local availability/fishing activity, or the growth patterns. The PBFWG may want to discuss about research plan on those matters to improve the future stock assessment.

4 ASSESSMENT RESULTS

Note that the results of this document were derived from a preliminary model and not necessarily the same with those of the stock assessment report. The formal results to consider the stock status and conservation information of this species will be developed by the PBFWG.

The update preliminary model derived similar results with the previous assessment (Fig. 2), although the estimates of SSB by the updated model were slightly higher than the previous assessment prior to the 1980's. The unfished SSB (SSB0) was estimated to be about 643 thousand t (R0 = 13.7 million fish) and was almost identical with the previous assessment. Spawning stock biomass (SSB) estimates exhibited long term fluctuations, and in the most recent two years, SSB continued to show a tendency of slight increase which has been appeared since 2010. The depletion ratio (SSB/SSB0) of the terminal year (2016) corresponded 3.3%.

The recruitment estimates were almost identical with the previous assessment. The recent two years (2015 and 2016) of the recruitments were 7.8 and 16.0 million fish, respectively, whereas the estimated unfished recruitment (R0) was 13.7 million fish.

5 SENSITIVITY

The results of four sensitivity analysis are presented (Fig. 3): sensitivity to (a) assigning to deferent data weighting to the size composition data, (b) the assumption if the model is fitted more closely to either of Japanese or Taiwanese longline CPUE based abundance indices; (c) the assumption if the model is fitted to the size composition data from Korean Large Offshore Purse Seine fleet (KLOPS: Fleet 3).

The size composition data was re-weighted by the ratio of the harmonic mean of estimated effN and the mean input sample size in case that ratio for each fleet is lower than 1.0. An alternative scenario of the data re-weighting for the size composition data did not substantially affect to the estimated SSB as well as the recruitment. And the model fit to the CPUE did not improved by this alternative assumption (Table 2).

There was no significant difference in the estimated SSB and recruitment among the updated model and sensitivity runs with an alternative assumption if the model is fitted more closely to either of Japanese or Taiwanese longline CPUEs. The RMSE between observed and predicted abundance indices for those indices were improved by those alternative assumptions (Table 2).

There was also no significant difference in the estimated SSB and recruitment between the updated model and a sensitivity run with an assumption if the model is fitted closely to the size composition data from KLOPS fleet although the model fit to that size composition data were improved (Fig. 4).

6 References

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Table 1 Likelihood profile for a parameter for the fixed log unfished recruitment (log R0) estimated by the updated model. The relative likelihood values were shown for each data component.

Log_R0	9.3	9.35	9.4	9.45	9.5	9.55	9.6	9.65	9.7
TOTAL	48.84	28.92	15.67	5.58	0	0.11	3.33	7.56	12.78
Catch	0.96	0.97	0.81	0.66	0.51	0.40	0.29	0.14	0
Survey	1.238	1.505	1.252	0.269	0	0.308	2.58	5.888	9.748
SizeFreq	15.11	7.14	2.95	0.44	0	1.48	2.42	3.01	3.77
Recruitment	33.03	20.83	12.24	6.13	1.85	0.13	0.00	0.13589	0.51

Table 2 The-root-mean-square-error (RMSE) for catch per unit of effort based abundance indices for the updated model and sensitivity models.

Model	S1 JpCLL late	S2 JpnDWLL earl	S3 JpnDWLL mic	S5 JpnTroll	S9 TWLLSouth
Updated model	0.302	0.212	0.151	0.188	0.289
Sens; reweight	0.301	0.205	0.149	0.182	0.288
Sens; fit JLL	0.268	0.211	0.149	0.190	0.273
Sens; fit TLL	0.306	0.211	0.149	0.189	0.280
Sens; fit KLOPS size	0.301	0.212	0.149	0.191	0.289

Table 3 Mean input sample size and model estimated mean variance (effN) for the updated model, where effN is the models estimate of the statistical precision.

Fleet	Fishery	Ncomp	mean_effN	mean(inputN)	HarMean(effN)	MeaneffN /MeaninputN	HarMean(effN) /inputN
1	JLL	73	56.20	8.47	26.80	6.64	3.17
2	JSPPS(S1,3,4)	39	22.48	10.95	13.33	2.05	1.22
4	TPSJS	29	36.19	19.97	16.06	1.81	0.80
5	TPSPO	11	49.88	9.64	42.33	5.18	4.39
6	JTroll(S2-4)	52	30.50	9.85	14.67	3.10	1.49
8	JSN(S1-3)	70	18.89	6.57	12.06	2.88	1.84
9	JSN(S4)	24	21.11	7.03	15.41	3.00	2.19
10	JSN(HK_AM)	23	31.96	8.97	15.65	3.57	1.75
12	TWLLSouth	25	94.55	12.76	36.67	7.41	2.87
13	USCOMM	50	19.10	14.49	6.15	1.32	0.42
14	MEXCOMM	14	23.37	10.36	15.69	2.26	1.51
17	TWLLNorth	8	71.66	2.61	57.73	27.43	22.10
18	JSPPS(S2)	12	23.75	11.25	13.50	2.11	1.20
19	JTroll(S1)	18	27.10	7.22	12.21	3.75	1.69

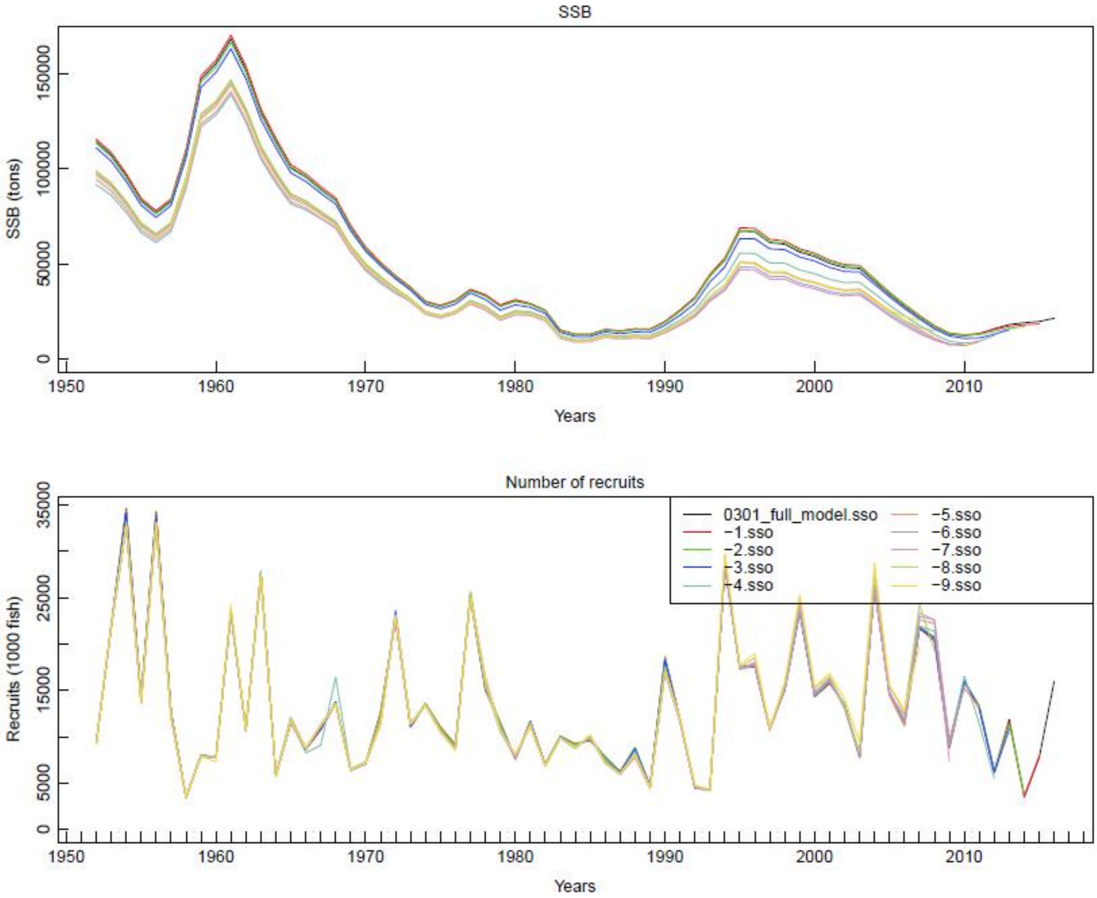

Figure 1 Nine-year retrospective analysis of the spawning stock biomass (upper) and recruitment (bottom) from the updated model. Each line represents a model results with sequentially one less terminal year of data.

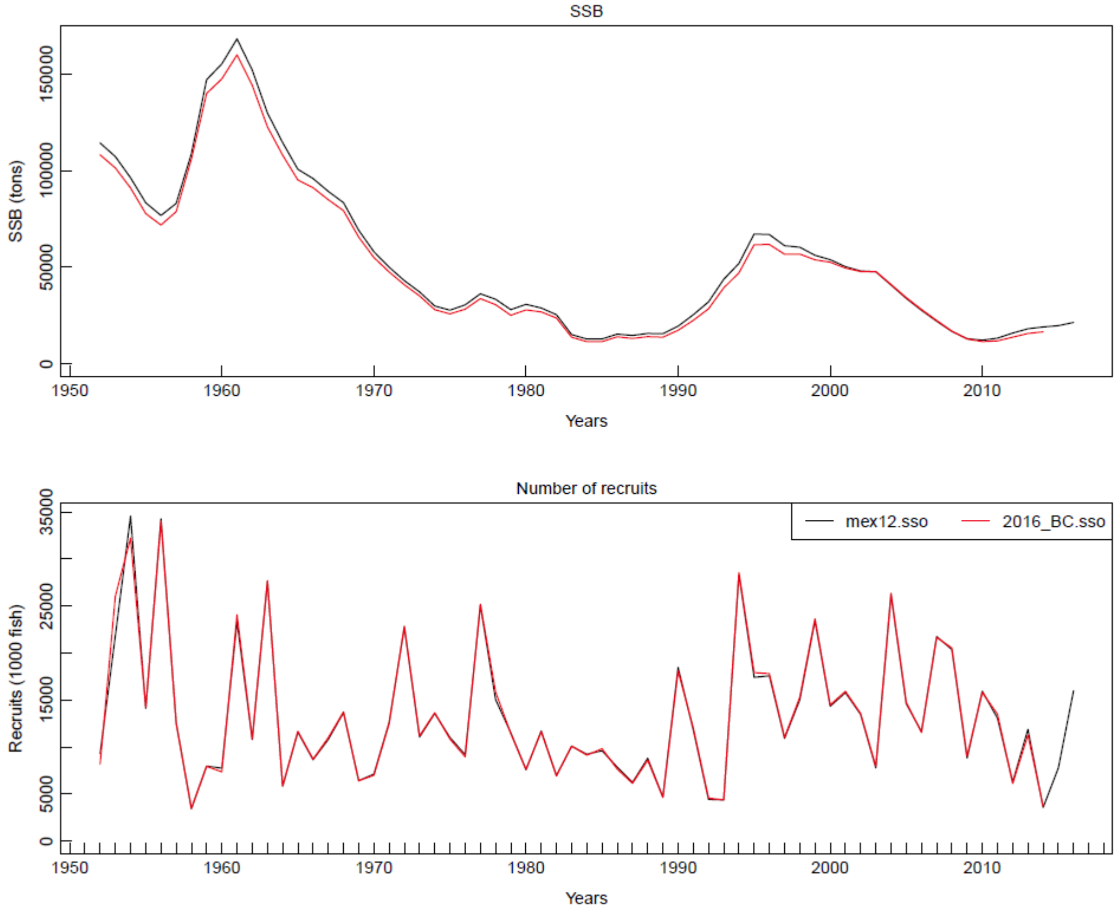

Figure 2 Estimated SSB (upper) and recruitment (bottom) from the updated model (black line) and base case model in the 2016 Pacific bluefin tuna stock assessment (red line).

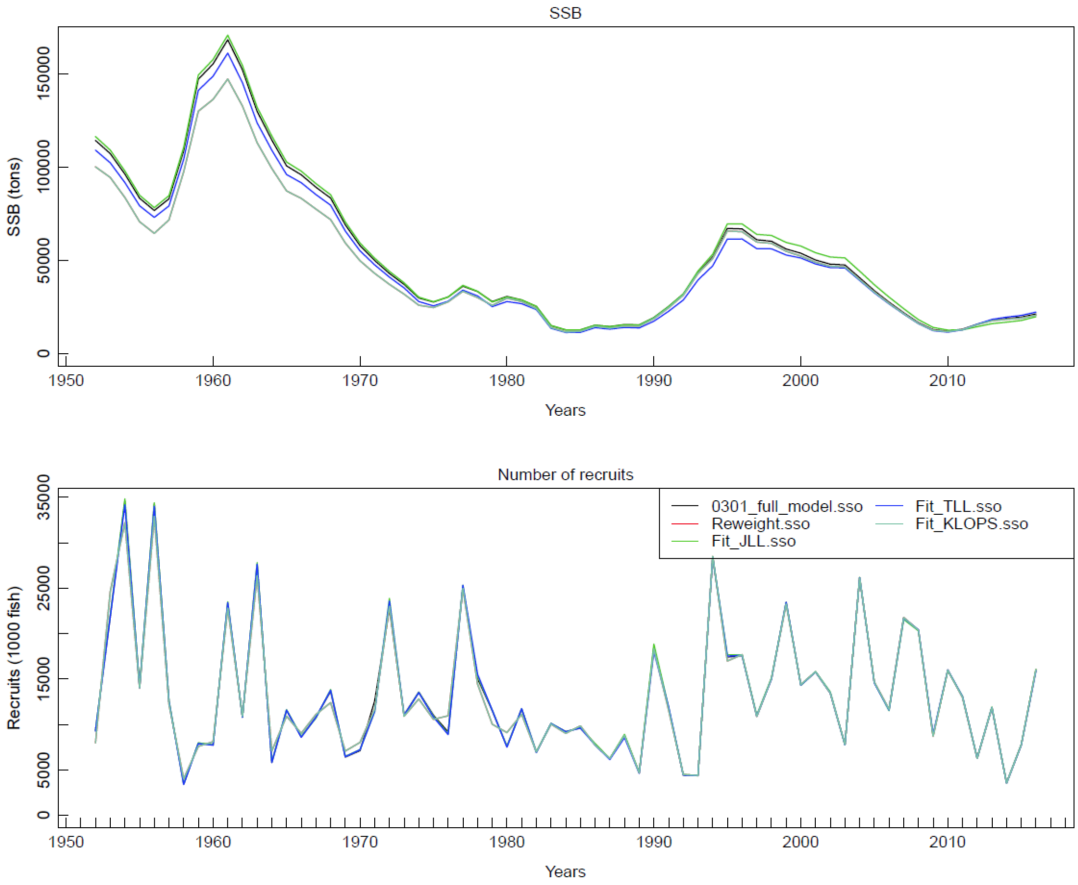

Figure 3 Estimated SSB (upper) and recruitment (bottom) from the updated model and sensitivity models.

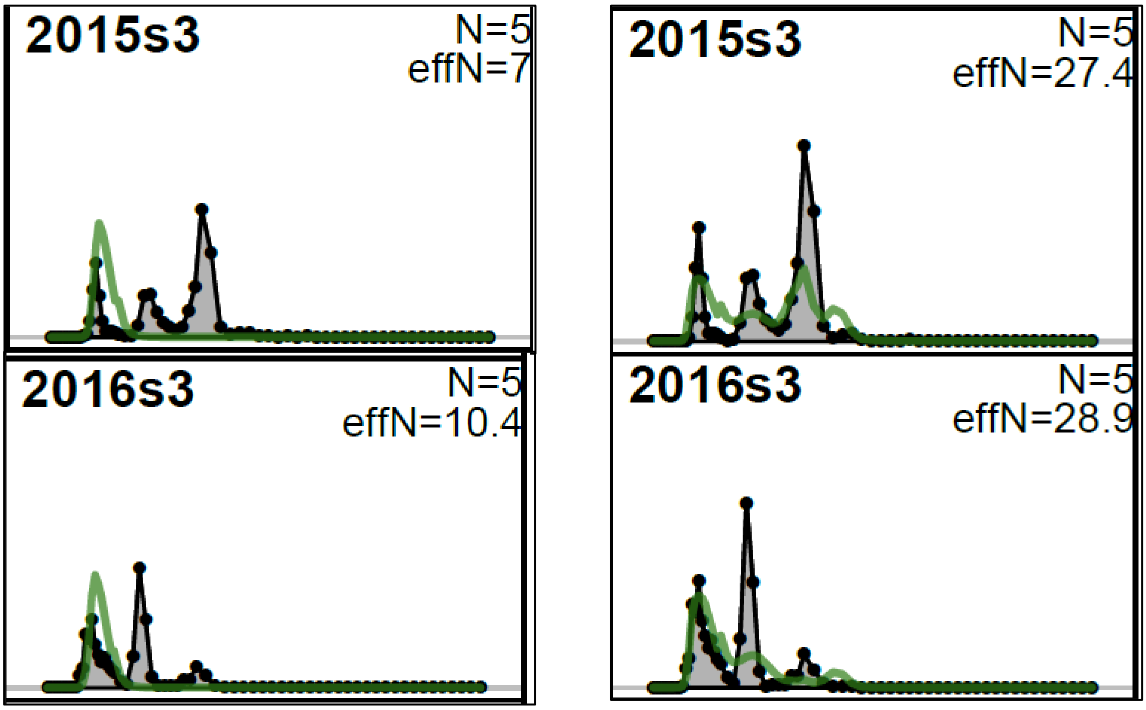

Figure 4 Model fit to the quarterly size composition data from the Korean Large Offshore Purse Seine fleet (Fleet 3) of the updated model (left panel) and Sensitivity model (right panel).