Area weighted size composition data for estimation in a selectivity of Japanese longline index standardized by spatio-temporal model

Yohei Tsukahara and Hiromu Fukuda

Highly Migratory Resources Division, Fisheries Resources Institute,
Japan Fisheries Research and Education Agency
2-12-4, Fukuura, Kanazawa-ku, Yokohama, Kanagawa 236-8648, JAPAN

February 2024

Working document submitted to the ISC Pacific bluefin tuna Working Group, International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), from 29 February to 8 March 2024, Kaohsiung Taiwan.

Summary

The stock assessment for Pacific bluefin tuna uses an adult abundance index using the catch-per-unit-effort data for Japanese longline fishery. There is an inconsistency of the data treatment in terms of spatial weighting between abundance index and catch-at-size data. This document describes an alternative size composition data for the abundance index, using product weight data recorded in logbook. The performance of the area weighted size composition data was evaluated by the short-term assessment model the PBFWG developed in 2022. The area weighted size composition data showed similar results to traditional CAS raised by landing weight by main ports, while the frequency in larger size, was less than traditional one. The authors present that this exercise made the JLL index and its selectivity more consistent, although we have concern on the use of the same data.

1. Introduction

The stock assessment for Pacific bluefin tuna (PBF) uses the catch-per-unit-effort (CPUE) data for Japanese longline fishery (JLL) as an abundance index of spawner population (ISC 2022). The JLL operates for PBF mainly in the Pacific coastal area of Japan, including spawning area around Nansei archipelago during spawning season. The CPUE of this fishery since 1994 was standardized by spatio-temporal model to take the precise spatial structure of availability into account (Tsukahara et al, 2022). In this standardization, the geographical effect was dealt with as the grids of 1x1 degree of longitude and latitude. As a result, the predicted index from this analysis has equally weighted abundance information in every grid. This treatment makes the index more unbiased in terms of the annual and seasonal differences in spatial availability of PBFs.

On the other hand, the selectivity for this index was assumed to be same as it estimated by the size of removal by this fisher in spawning season y, i.e., selectivity of Fleet 1 in the assessment (ISC 2022). The input catch-at-size (CAS) data for Fleet 1 is body length measurement data raised by the catch amount by main fishing port. The measurement data, therefore, is raised regardless of the area of fishing ground, resulting in the spatially unequally weighted CAS. For example, if the fishing operation is concentrated in the limited area such as spawning ground and the harvest is landed in the nearest port, the size information in such area has higher impact on the shape of CAS compared to that in the other fishing ground. Although the PBFWG address the additional data treatment, e.g., removing less than 150 cm fish from the data for the CAS, there is inconsistency of the data treatment in terms of spatial weighting between abundance index and CAS.

This document describes an alternative size composition data for abundance index based on the JLL CPUE. The alternative size composition data is designed to have equal weights across the 1x1 grid used in the standardization. In addition, it was investigated if alternative size composition data perform better in terms of the consistency in the assessment.

2. Materials and Methods

2.1. Data and data curation

Most of the size composition data in the PBF stock assessment are length-based composition data, rather than weight composition data because the body length just increases irreversibly. The Fishery Resources Institute in Japan conducts a survey to collect the measurement data of the body length in the landing port. The results of the survey were utilized to estimate the catch-at-size for each fleet in the assessment, including JLL fleet. However, the information on the fishing location is limited in this survey because of nature of the port-sampling. In the case of harvest by longliner, interview survey for fishermen have been initiated since 2001, while the coverage of location data over the entire measurement data depends on the ports, resulting in the spatially biased data quantity across the fishing ground. Therefore, another data source which has location information is required to make the area weighted size composition.

The logbook data reported by the longline fishermen is a data source for the CPUE standardization because it contains detailed information on each operation, including the number of used hook, fishing location, and catch in number and weight by species. The catch in weight here is not individual weight, but total in an operation. However, in the case of PBF, they are often caught as one fish in an operation due to their availability. The catch in weight data with fishing location information in logbook could be a data source to develop an alternative weight-based size composition in weight. In this document, we excluded the weight data when more than two PBF were caught in one operation to prioritize the data accuracy rather than to increase the amount of data with averaged weight. Because the individual weight recorded in the logbook is product weights, the weight for area weighted size composition was multiplied by 1.16 according to a general conversion factor from the weight without gill and gut to the weight of whole fish.

The weight composition requires the definition of weight bin, b. There are 2 fleets whose size data are weight composition. However, the maximum weight of the weight composition is 273 kg because most of the harvests by those fisheries are relatively small fish. Hence, the bins were originally set as it is in the existing fleets for less than 70 kg, 10kg interval from 70 kg to 400kg, 20 kg interval from 400kg to 500kg. As a result, the number of bins is 51. The catch in weight when only one fish was aggregated into the grids of 1x1 degree of longitude and latitude, g, by year, y, and bins. The actual count in each aggregation was divided by the total number of catch in the grid and the year for summation to be 1. Finally, the size composition in each grid was added up by year (**Figure 1** and **Equation 1**).

$$Weight\ Comp_{y,b} = \sum_g \frac{Catch\ in\ number_{y,g,b}}{Catch\ in\ number_{y,g}} \qquad \text{(Eq. 1)}$$

2.2. Performance evaluation with the 2022 assessment model

The performance of the area weighted size composition data was evaluated by the short-term assessment model the PBFWG developed in 2022 (Fukuda 2022, hereafter called Model 0) with stock synthesis ver. 3.30.14.08. First, the selectivity settings for JLL fleet, i.e., removing the time block and estimating p6, were modified according to the decision in the PBFWG (ISC 2023). Second, the area weighted size composition data were applied to the data to estimate the selectivity for JLL index, while the selectivity settings for JLL catch fleet, Fleet 1, was as they were in 2022 model. Finally, the size composition data for less than 150 cm fish in fleet 1 were recovered, because the data was removed due to the consistency of data treatment with CPUE standardization. This model is hereafter called Model 1.

Because Model 1 is fully integrated model, the fit to the index and size data were affected by the multiple data sources. In this document, two ASPM tests with fixed recruitment deviation (ASPM-Rfix) were utilized to investigate the interaction just between JLL index and its selectivity estimated by either traditional CAS or area weighted size composition data. First ASPM-Rfix set the selectivity for JLL index as it estimated for Fleet 1 in Model 0 based on the traditional CAS (Model 2). The second ASPM-Rfix set the selectivity for JLL index as that estimated for JLL index in Model1 (Model 3). All of the other parameters including Fleet 1 selectivity for models 2 and 3 were fixed at maximum likelihood estimation in Model 1. The authors conducted the 50 times jitter analysis for every model to explore the best fit to each dataset. In the case of old Japanese longline index (S3) from 1983 to 1992 fishing year (July to following June), the standardization process did not take spatial effects into account, and thus the selectivity for this index is mirrored from JLL catch fleet, Fleet 1 as it was in the previous assessment.

3. Results and discussion

3.1. Area weighted CAS

The operations in the logbook were filtered out as those for CPUE standardization such as grid where the PBFs were caught for more than 5 years. As a results, the 47% of caught PBFs could be utilized for the area weighted size composition data, while the 73.3% of landed PBFs were measured by port sampling method. The lowest ratio of was 26.2% in 2019 fishing year.   There were a few grids where all of the PBF catches were more than two fishes to date. The weight information at those grids was not used for this analysis whereas the amount of information in terms of the number of the grids is not so much degraded compared to the grids using CPUE standardization. It is noted the increasing of PBF stock may bring the ratio lower for the future. It will be difficult to use logbook data for the size composition data for the future JLL index.

The annual area weighted size composition data are shown in Figure 2, compared to the weight converted traditional CAS. The general trend of size composition data was apparently similar to each other, while the frequencies for larger sized PBF of area weighted size composition were less than the traditional CAS. This is because the landings by JLL for spawning season tends to concentrate at the port around the limited spawning ground where the relatively larger PBFs are caught. The traditional CAS, therefore, was strongly affected by the landings around spawning ground. It is a good way to raise the size composition data for removal. On the other hand, area weighted size composition data have equal weight across the 1x1 grids. It reduced the impact in the certain main fishing ground.

3.2. Performance evaluation in the assessment model

The root mean squared error (RMSE) is used as an indicator to evaluate the fit to the JLL index. The RMSEs in each model were shown in Table 2. The difference in RMSE between Model 0 and Model 1 indicates that introducing area weighted size composition make fit to the JLL index slightly better. For the ASPM-Rfix analysis, Model 3 with selectivity of JLL index based on the area weighted size composition data showed much improvement, compared Model 2 with that based on the traditional CAS. Also, the introduction of the area weighted size composition did not affect negatively in terms of model fitting to the other longline indices (e.g. JLL index early period and TLL index).

Figure 3 shows the trajectories of expected indices and observed values for JLL index. Introducing area weighted size composition data, comparing Model 0 and Model 1, improved the fit to increase and decrease trend around 1999 fishing year. ASPM-Rfix tests indicates that the increasing trends since 2010 were better represented by the Model 3 with selectivity with area weighted size composition data, resulting in the substantially lower RMSE. The estimated selectivity for the JLL index in Model 1 was narrower than that for the catch fleet of JLL estimated in both Model 0 and Model 1 (Figure 4). The fit to the area weighted size composition in Model 1 was shown in Figure 5 and Figure 6. The overall fit to the size composition data other than the Japanese longline fleet (Fleet 1 and JLL index) became slightly worse when introducing size composition data (Model 0: 1447.45 -> Model 1: 1451.90) especially for Fleet 15 and 16. According to these observations, introducing area weighted size composition data addressed a theoretical inconsistency between the weighting methods of JLL index and its size composition data to estimate selectivity, and it improves model fits to the JLL index.

4. Conclusion

The alternative size composition data in this paper is considered to be theoretically consistent with current JLL index standardized by spatio-temporal model in terms of weighting across spatial grids. The area weighted size composition data showed similar results to traditional CAS raised by landing weight by main ports, while the frequency in larger size, which tend to be caught in around spawning ground, was less than traditional one. Introducing area weighted size composition data into the stock assessment also showed improvement of fit to the data. However, it should be noted that the length of substantial part of the PBF in logbook used for this document were subject to the port sampling, resulting in the use of the same information of a PBF for traditional CAS and area weighted size composition data. The authors present that this exercise made the JLL index and its selectivity more consistent according to the discussion in the PBFWG, although we have concern on the use of the same data.

References

International Scientific Committee for tuna and tuna-like species in the North Pacific Ocean (ISC). 2021. Report of the Pacific Bluefin Tuna Working Group Intersessional Workshop (April 20-27, 2021), ISC21 Plenary Report, Annex 12, 10 pp.

Methot Jr, R. D., Wetzel, C. R. 2013. Stock synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research, 142, 86-99.

Fukuda, H., Tsukahara, Y., and Nishikawa, N. 2022. Update of the PBF population dynamics model using short time series data (1983-) and the sensitivity runs for the robustness test. ISC/22/PBFWG-1/06.

Tsukahara, Y., Asai, S., Fukuda, H., Nakatsuka, S. 2021. Standardized CPUE for Pacific Bluefin tuna caught by Japanese coastal and offshore longline in 2022 update assessment. ISC/22/PBFWG-1/01.

Table 1 The numbers of data for area weighted size composition. The number of grids where are no weight means that there are PBF catches, whereas all of those are more than two PBFs caught at one operation. The totals in bottom row for the numbers in 3rd, 4th, 6th and 7th columns are summations and for the ratio in 5th column is average.

Year	Fishing Year	The number of caught PBFs of only 1 PBF caught	Total number of caught PBFs	Ratio of PBFs of only 1 PBF caught	# of grids where there are PBF catch	# of grids where there are no catch of only 1 PBF caught
1994	1993	874	2687	0.325	55	1
1995	1994	698	1574	0.443	68	0
1996	1995	961	2471	0.389	64	2
1997	1996	706	2589	0.273	85	4
1998	1997	915	3097	0.295	89	3
1999	1998	1079	3823	0.282	85	5
2000	1999	987	2300	0.429	92	3
2001	2000	958	1813	0.528	76	3
2002	2001	1111	2094	0.531	88	3
2003	2002	967	2618	0.369	90	8
2004	2003	1292	3634	0.356	103	4
2005	2004	1256	3783	0.332	100	5
2006	2005	976	1981	0.493	93	4
2007	2006	1031	2953	0.349	74	1
2008	2007	863	1454	0.594	90	3
2009	2008	537	1251	0.429	73	7
2010	2009	445	686	0.649	43	1
2011	2010	272	442	0.615	42	1
2012	2011	260	360	0.722	52	2
2013	2012	499	735	0.679	62	1
2014	2013	494	670	0.737	59	0
2015	2014	351	507	0.692	57	1
2016	2015	355	607	0.585	53	1
2017	2016	603	1186	0.508	72	0
2018	2017	178	381	0.467	38	1
2019	2018	408	1159	0.352	66	7
2020	2019	209	797	0.262	51	5
Total		19285	47652	0.470	1920	76

Table 2 Root mean squared error (RMSE) for the abundance indices in each model.

RSME in each index	Model 0	Model 1	Model 2	Model 3
Type of model	Fully Integrated model	Fully Integrated model	ASPM-R with fixed rec devs	ASPM-R with fixed rec devs
S1JpCLL	0.289	0.286	0.292	0.273
S3JpnDWLLYokawaRevfrom75	0.158	0.144	0.147	0.148
S4JpnTrollChinaSea	0.214	0.216	0.215	0.214
S5TWLLSouth	0.249	0.246	0.242	0.241

Table 3 Negative log-likelihood values for size composition by fleets.

Fleet name	Fleet number	Model 0	Model 1	Note
F1JLL	Fleet 1	42.87	73.20	Model 1 includes less than 151 cm
F2JSPPS(S1,3,4)	Fleet 2	149.42	149.36	No change in input data
F3KOLPS	Fleet 3	56.38	56.29	No change in input data
F4TPSJS	Fleet 4	82.47	82.77	No change in input data
F5TPSPO	Fleet 5	49.87	50.37	No change in input data
F6JTroll(S2-4)	Fleet 6	177.86	177.76	No change in input data
F8JSN(S1-3)	Fleet 8	369.28	369.10	No change in input data
F9JSN(S4)	Fleet 9	102.70	102.20	No change in input data
F10JSN(HK_AM)	Fleet 10	44.68	44.53	No change in input data
F12TWLLSouth	Fleet 12	40.01	39.71	No change in input data
F13USCOMM(-2001)	Fleet 13	0.25	0.41	No change in input data
F14MEXCOMM(2002-)	Fleet 14	40.47	43.22	No change in input data
F15EPOSports	Fleet 15	88.73	89.49	No change in input data
F17TWLLNorth	Fleet 17	3.70	3.70	No change in input data
F18JSPPS(S2)	Fleet 18	62.21	64.71	No change in input data
F19JTroll(S1)	Fleet 19	56.53	56.46	No change in input data
F20JSPPS(Penning)	Fleet 20	29.68	29.63	No change in input data
S1JpCLL	Fleet 21	0.00	36.83	Model 1 has area weighted size comp
F23JLL(1993-S1-3)	Fleet 28	93.21	92.20	No change in input data
Total		1490.32	1561.93	
Total other than Fleet 1 and Fleet 21		1447.45	1451.90	

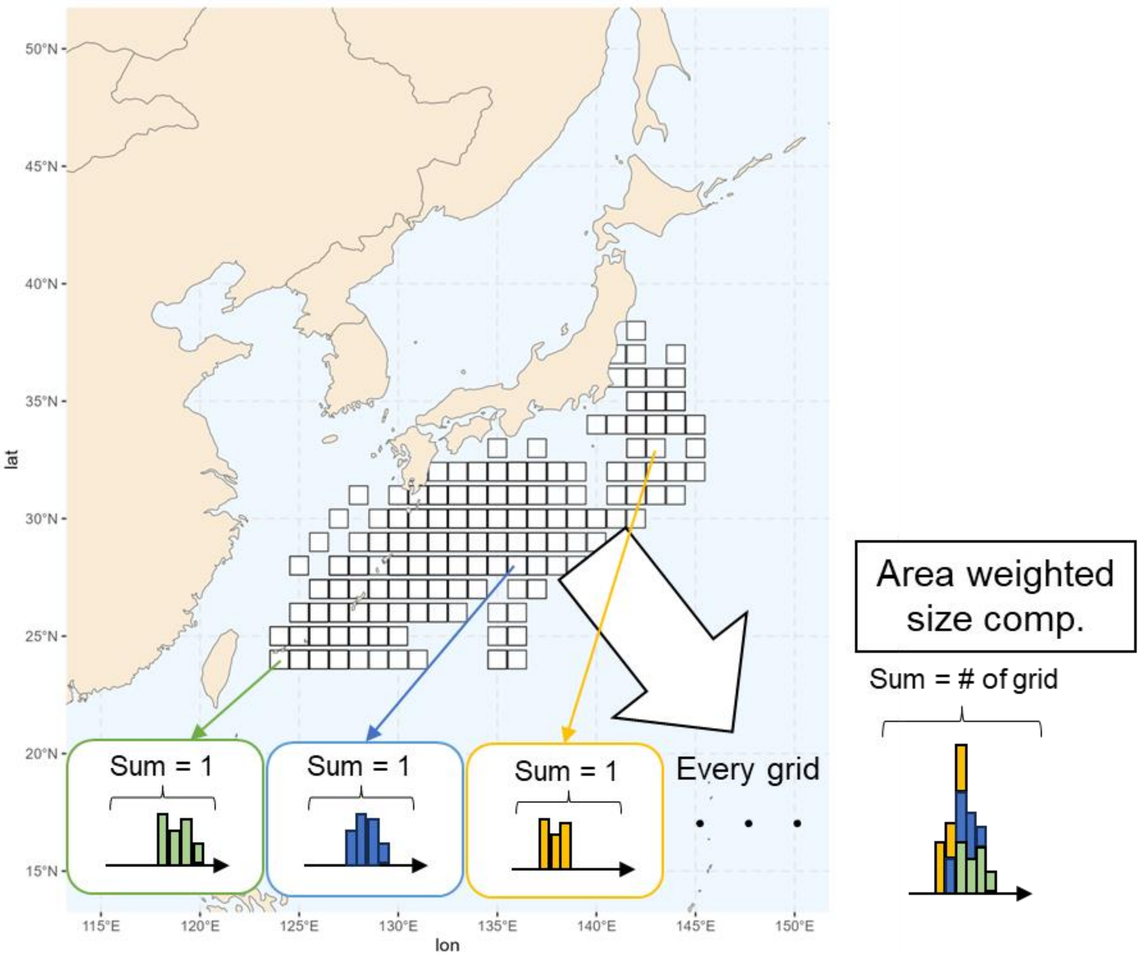

Figure 1. Image of the summation of area weighted size composition data.

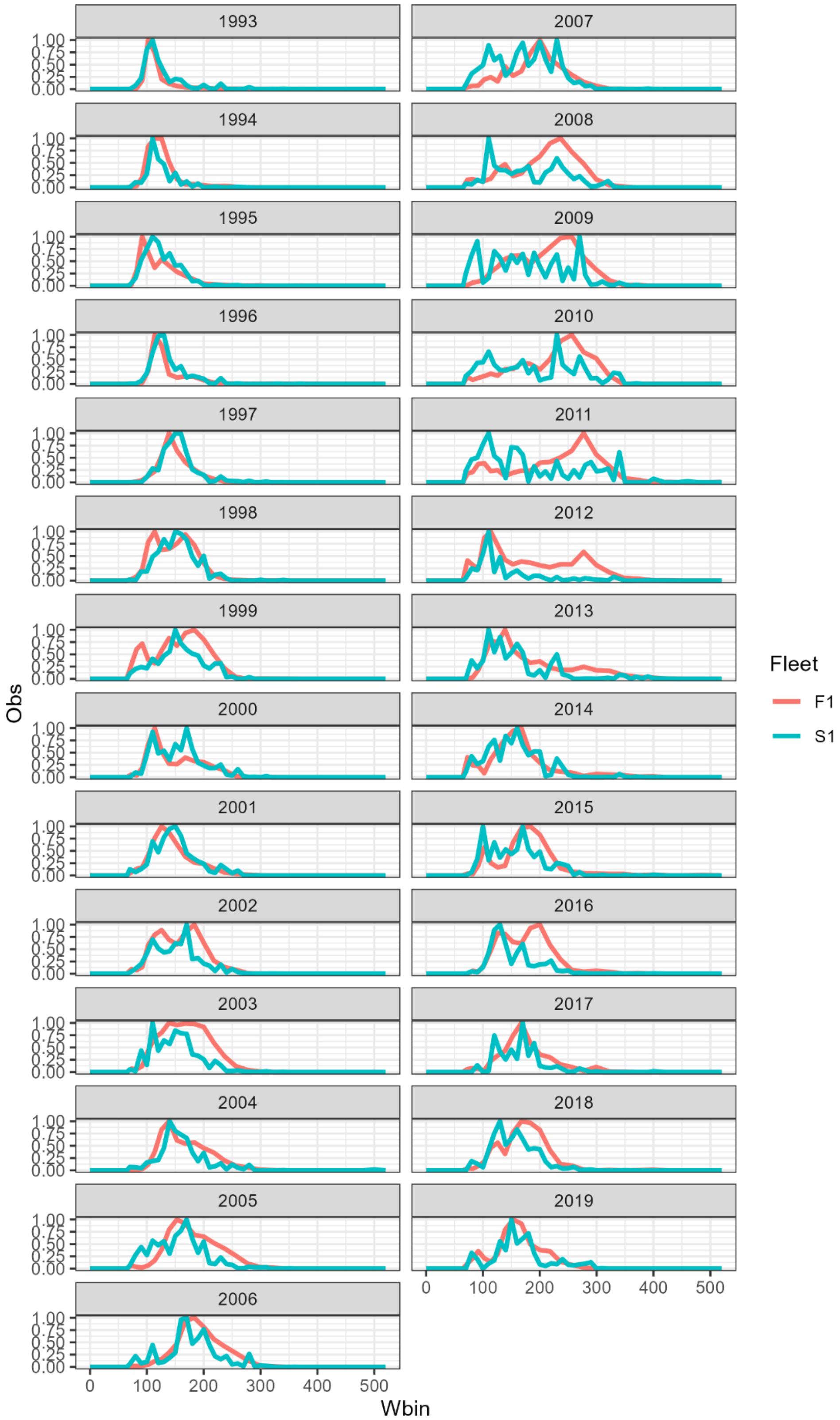

Figure 2. Annual frequencies of area weighted size composition (Blue) data and traditional catch-at-size for Fleet 1 (Red).

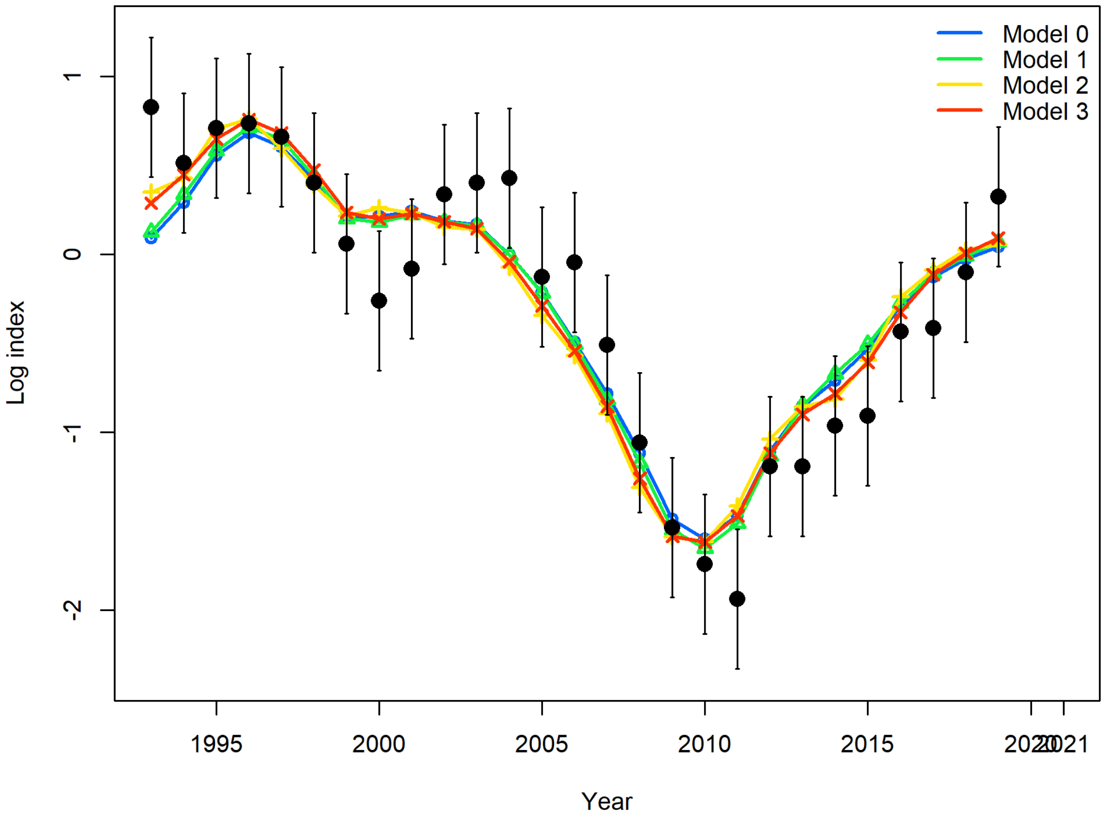

Figure 3. Comparison between the expectations in each model and observations. Model 0 is the basically previous base short model. Model 2 is introducing the area weighted CAS. Model 2 is ASPM-Rfix with selectivity based on the traditional CAS for JLL index. Model 3 is ASPM-Rfix with selectivity based on the area weighted size composition data for JLL index.

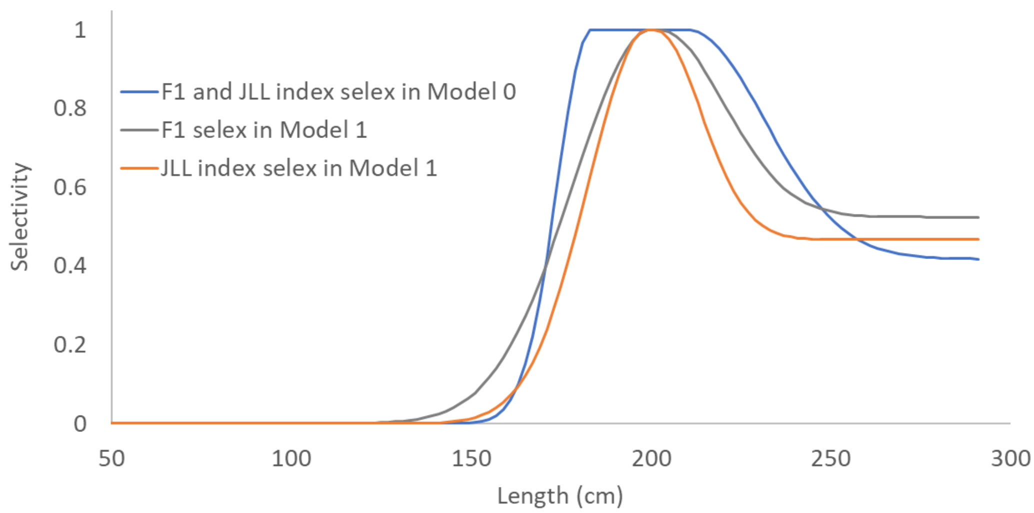

Figure 4. The shapes of length selectivity for JLL catch fleet and JLL index fleet in Model 0 and Model 1, respectively. In the case of model 0, the shapes for those are identical.

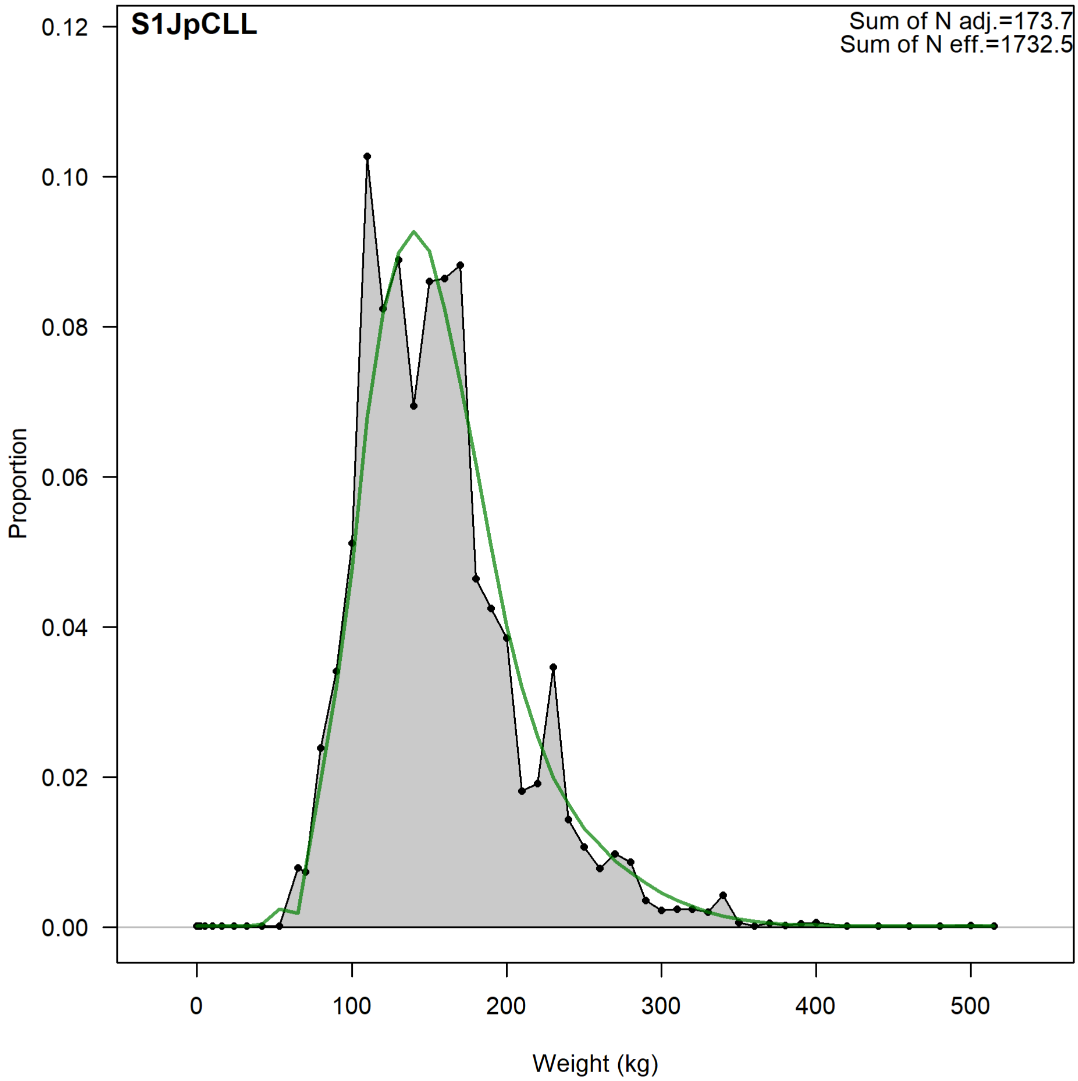

Figure 5. Overall fit to the observation data of area weighted size composition for Japanese longline index.

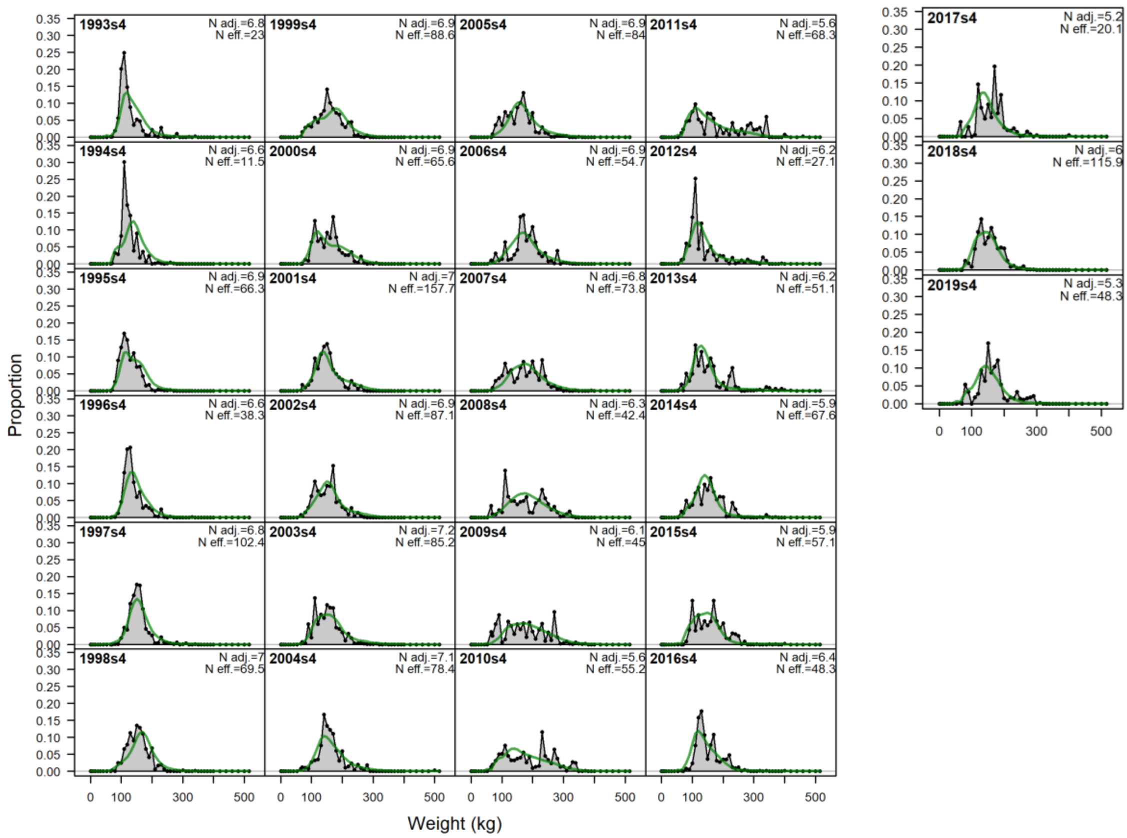

Figure 6. Annual fit to the observation data of area weighted size composition for Japanese longline index.