Selection of an abundance index and its selectivity for the 2024 PBF assessment

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1 Introduction

In the stock assessment of the Pacific bluefin tuna (*Thunnus Orientalis*, PBF), the key data sources were the indices of abundance based on the Catch Per Unit of Effort (CPUE) from two longline fleets (Japanese and Taiwanese longline), which informed the trend of large adult PBF population. After comprehensive analysis, evaluation, and discussion about those CPUEs for many years, current data structure of the longline abundance indices was developed in the 2016 PBF benchmark stock assessment and updated at the 2020 benchmark assessment (cutoff early 2 years data points). However, during the process of the 2022 PBF update stock assessment, Tsukahara et al. (2022) reported a possible change in catchability of Japanese longline fleet due to the introduction of the new management scheme (e.g. Individual Quata management) starting from 2020 fishing year. In accordance with this report, the PBFWG decided to exclude Japanese longline index after 2019 fishing year. Eventually, Taiwanese longline CPUE index became a single index of abundance in the PBF assessment model which maintained its continuity until the terminal year of the 2022 stock assessment. To date, several new research programs were started to develop the alternative of the Japanese longline CPUE index (Tawa et al., 2023), but it might not be realistic to have multiple index of adult abundance for the next benchmark assessment in 2024.

Although Taiwanese longline CPUE index was the only and important input data for the assessment, Fukuda (2023) conducted a series of retrospective analysis on the short-term PBF assessment model, and it pointed out that Taiwanese longline CPUE index possibly caused an instable estimation of the SSB. Taiwanese longline CPUE index currently used was standardized using a delta-generalized linear mix model (delta-GLMM) without consideration of the spatial effect (Chang et al., 2020). This was a traditional method and the PBFWG chose this method to prioritize the length of time series, where a CPUE standardized by the vector-auto-regressive spatiotemporal model (VAST) which considered spatial effect, was also available. The traditional GLMM standardization method generally worked well in the context of the PBF stock assessment, but recent research showed an occurrence of new fishing ground in Southwestern coastal side of the Taiwan main island for both PBF and non-tuna species, and the size composition data have been stably distributed since 2019 calendar year at smaller size than 2010’s (Chang et al., 2023). Although the relationship between the fishing ground and size composition is not clear, there would be a possibility that a change in the size selectivity of fishery, which could lead to a change in catchability of fishery. If this happens, current traditional CPUE standardization method could not extract the annual change in relative abundance because the spatial effect and size-related effect was not considered.

On the other hand, Taiwanese researchers further analyzed its longline CPUE standardization using a spatio-temporal VAST model incorporating SST and age group data (Yuan et al., 2023). Although this new method has a shorter time series than the traditional GLMM index due to the data availability, it has an advantage which incorporated the spatial and size effect on the catchability of PBF. Given a recent situation of Taiwanese longline fleet, whose operation dynamics might have changed, this new method may have an advantage. The purpose of this document is to test the Taiwanese longline CPUE index using VAST incorporating the age group effect.

2 Materials and Method

1.) Data

For testing an abundance index of large adult, it was important to use an internally consistent model to eliminate the noise given by a biased data. Fukuda et al. (2023) found that the recent (2011-2016) recruitment index would be negatively biased and this contributed to the systematic retrospective pattern of the PBF stock assessment model. In here, the modified version of the short-term PBF stock synthesis (SS) model, which excluded the recruitment index (S4) for 2011-2016, was used. For the comparisons, 7 types of the data structure about the Taiwanese longline index were tested as below;

(1) No Taiwanese longline index in the model;
(2) South area index standardized by Traditional delta-GLMM;
(3) Age 6-8 specific index standardized by VAST model;
(4) Age 9-11 specific index standardized by VAST model;
(5) Age 12-14 specific index standardized by VAST model;
(6) Age 15-17 specific index standardized by VAST model;
(7) Age 18-20 specific index standardized by VAST model.

Although Yuan et al. (2023) provided indices by Age 21-23 and 23+, because the current PBF assessment model considered age 20 and older as plus group, we did not test those indices.

Catch, Size composition, and the rest of the indices were same with the short-term PBF model except the recruitment index (S4) which was excluded during 2011-2016. The list of the tested models was shown in Table 1.

Table 1 Model specifications of the tested models.

Model No.	Fully integrated model	Data fitted in the model					Parameter estimated/fixed				
		Catch	Size	JLL index	TLL index	Age-0 index	Log R_0	Initial F	Recruit deviation	Selectivity	Selectivity of TLL index
1	Short_noTLL_Rind2010	Yes	Yes	Yes	No	Yes (to 2010)	Est.	Est.	Est.	Est.	-
2	Short_S5_Rind2010	Yes	Yes	Yes	Yes (S5)	Yes (to 2010)	Est.	Est.	Est.	Est.	Asymptotic size selex(est)
3	Short_S32_Rind2010	Yes	Yes	Yes	Yes (S32)	Yes (to 2010)	Est.	Est.	Est.	Est.	Age6-8 (full selection)
4	Short_S33_Rind2010	Yes	Yes	Yes	Yes (S33)	Yes (to 2010)	Est.	Est.	Est.	Est.	Age9-11 (full selection)
5	Short_S34_Rind2010	Yes	Yes	Yes	Yes (S34)	Yes (to 2010)	Est.	Est.	Est.	Est.	Age12-14 (full selection)
6	Short_S35_Rind2010	Yes	Yes	Yes	Yes (S35)	Yes (to 2010)	Est.	Est.	Est.	Est.	Age15-17 (full selection)
7	Short_S36_Rind2010	Yes	Yes	Yes	Yes (S36)	Yes (to 2010)	Est.	Est.	Est.	Est.	Age18-20 (full selection)
Model No.	ASPM+R_{fix}	Data fitted in the model					Parameter estimated/fixed				
		Catch	Size	JLL index	TLL index	Age-0 index	Log R_0	Initial F	Recruit deviation	Selectivity	Selectivity of TLL index
8	ASPM+R_{fix}-1	Yes	No	Yes	No	No	Est.	Est.	Fixed at Mod_1 value	Fixed at Mod_1 value	-
9	ASPM+R_{fix}-2	Yes	No	Yes	Yes (S5)	No	Est.	Est.	Fixed at Mod_1 value	Fixed at Mod_1 value	Asymptotic size selex(fixed)
10	ASPM+R_{fix}-3	Yes	No	Yes	Yes (S32)	No	Est.	Est.	Fixed at Mod_1 value	Fixed at Mod_1 value	Age6-8 (full selection)
11	ASPM+R_{fix}-4	Yes	No	Yes	Yes (S33)	No	Est.	Est.	Fixed at Mod_1 value	Fixed at Mod_1 value	Age9-11 (full selection)
12	ASPM+R_{fix}-5	Yes	No	Yes	Yes (S34)	No	Est.	Est.	Fixed at Mod_1 value	Fixed at Mod_1 value	Age12-14 (full selection)
13	ASPM+R_{fix}-6	Yes	No	Yes	Yes (S35)	No	Est.	Est.	Fixed at Mod_1 value	Fixed at Mod_1 value	Age15-17 (full selection)
14	ASPM+R_{fix}-7	Yes	No	Yes	Yes (S36)	No	Est.	Est.	Fixed at Mod_1 value	Fixed at Mod_1 value	Age18-20 (full selection)

Table 2 Root Mean Square Error for index of abundance and negative log likelihood for size composition data by each model. A shaded cell indicated that the index was not included in the likelihood function of the model.

Model No.	Full_model	Root Mean Square Error for index fit										Likelihood Size total
		JLL_S1 (1993-2019)	JLL_S2 (to1992)	J_troll	TLL (GLMM)	TLL_Vast						
						No_size	Age6-8	Age9-11	Age12-14	Age15-17	Age18-20	
1	Short_noTLL_Rind2010	0.24	0.16	0.18	0.47	0.38	0.41	0.87	1.05	0.92	0.30	1490
2	Short_S5_Rind2010	0.29	0.16	0.17	0.24	0.22	0.44	0.61	0.66	0.56	0.31	1494
3	Short_S32_Rind2010	0.23	0.16	0.18	0.49	0.39	0.19	0.90	1.20	1.08	0.31	1496
4	Short_S33_Rind2010	0.30	0.16	0.18	0.33	0.26	0.49	0.26	0.82	0.98	0.31	1501
5	Short_S34_Rind2010	0.32	0.16	0.17	0.19	0.22	0.63	0.59	0.27	0.29	0.31	1502
6	Short_S35_Rind2010	0.29	0.16	0.18	0.25	0.22	0.60	0.73	0.48	0.22	0.35	1500
7	Short_S36_Rind2010	0.25	0.16	0.18	0.46	0.37	0.40	0.88	1.02	0.90	0.27	1491
Model No.	ASPMR_fix	JLL_S1 (1993-2019)	JLL_S2 (to1992)	J_troll	TLL (GLMM)	TLL_Vast						Likelihood
						No_size	Age6-8	Age9-11	Age12-14	Age15-17	Age18-20	Size total
8	ASPM+R_{fix}-1	0.22	0.17	0.18	0.50	0.41	0.41	0.88	1.07	0.94	0.31	-
9	ASPM+R_{fix}-2	0.26	0.16	0.18	0.41	0.34	0.52	0.80	0.83	0.68	0.34	-
10	ASPM+R_{fix}-3	0.22	0.16	0.18	0.54	0.44	0.37	0.92	1.18	1.07	0.34	-
11	ASPM+R_{fix}-4	0.26	0.18	0.18	0.41	0.34	0.53	0.80	0.82	0.67	0.33	-
12	ASPM+R_{fix}-5	0.36	0.26	0.18	0.38	0.35	0.71	0.77	0.59	0.44	0.38	-
13	ASPM+R_{fix}-6	0.33	0.25	0.18	0.38	0.34	0.67	0.77	0.64	0.49	0.37	-
14	ASPM+R_{fix}-7	0.22	0.16	0.18	0.49	0.40	0.42	0.87	1.05	0.92	0.31	-

2.) Selectivity of index

The selectivity of the Taiwanese longline index in model-2 was assumed same as that of the Taiwanese longline fishery operating in the south area (Fleet 12 in the model), which was estimated by fitting to the size composition data of that fleet (current assessment method) (Fig. 1a). For Taiwanese longline indices in model-3 to 7, because the CPUE standardization method assumed that the catchability could differ by age groups but similar within the age group even though the size (age) was different, we assumed a constant full selection as given value for each target age (Fig. 1b-f).

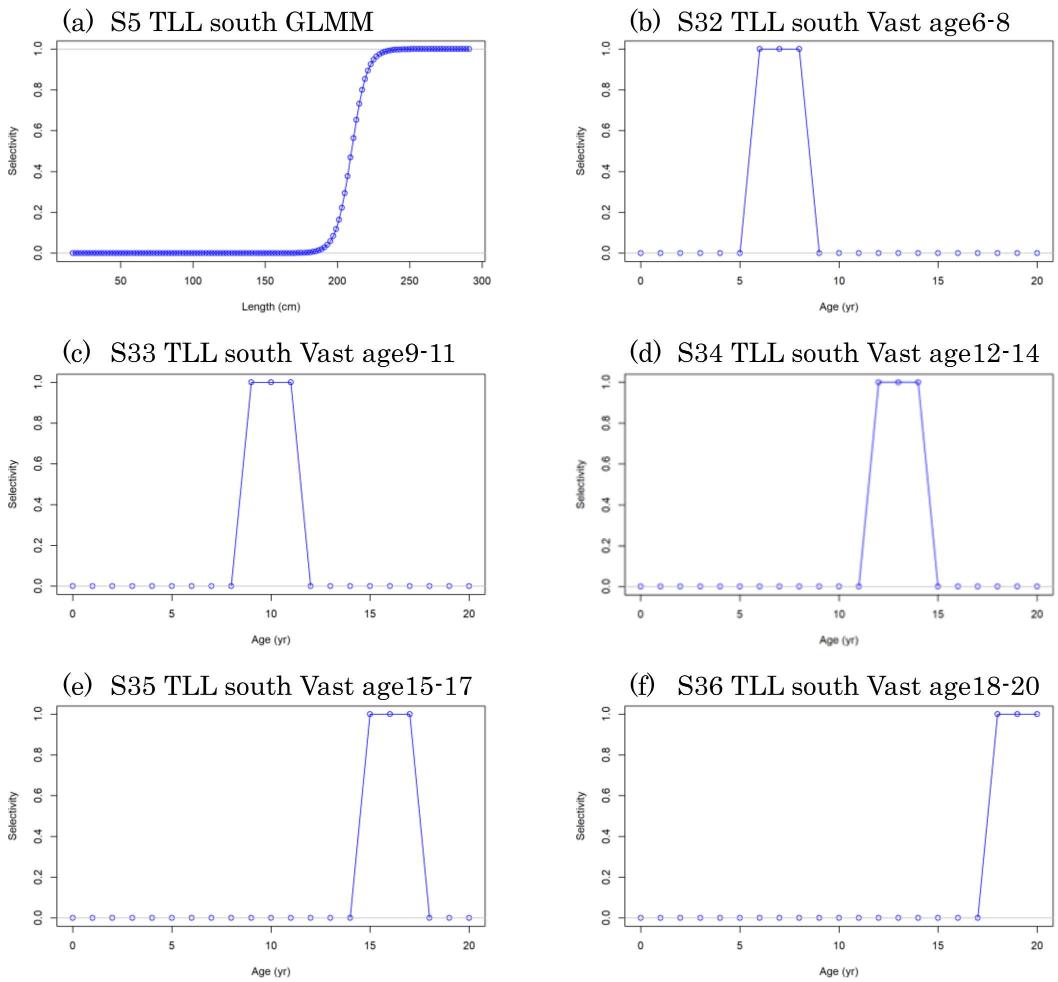

Figure 1 Length or age selectivity for each of Taiwanese longline CPUE based index.

3.) Analysis

To evaluate the consistency of the Taiwanese longline CPUE index with other data in the model, we tested the candidates of Taiwanese longline CPUE index using the fully integrated model run and Age Structured Production Model with the fixed recruitment variability (ASPM+R_{fix}) analysis (Table 1). In particular, the consistency between the Japanese longline data, which was another index of adult abundance, in the ASPM+R_{fix} was employed as an indicator of consistency. Because ASPM+R_{fix} basically estimated only few parameters related to the population scale under the given selectivity and recruitment variability, a degraded fit to the Japanese longline index could be an indication of the conflicted data about the population scale.

For the tested index which passed ASPM+R_{fix} test, we additionally conducted a retrospective diagnostics on that fully integrated model.

3 Results

1.) Age structured production model with fixed recruitment variation

Table 2 showed the root mean square error (RMSE) for each index of abundance. Figure 3 showed a comparison of model fit to the Japanese longline index for the fully integrated model and the ASPM+R_{fix}. For both model structures, model 1 and ASPM+R_{fix}-1, which did not include Taiwanese longline CPUE index, showed a good fit to the Japanese longline index (Fig. 3a and 3b, Table 2). It was natural by structure of the input data, because there was only a single index of abundance to inform the trend of the large adult PBF population in a period. Among the model runs including Taiwanese longline index, ASPM+R_{fix}-3 and ASPM+R_{fix}-7, which included TLL VAST-index for age 6-8 and age 18-20, respectively, showed a similar RMSE value with that of the ASPM+R_{fix}-1. This indicated that TLL VAST-index for age 6-8 or age 18-20 did not impede the model fitting to the JLL index, so the model could predict the trend of the observed JLL index at same degree with ASPM+R_{fix}-1. This is an indication of the consistency between the JLL index and TLL VAST index for age 6-8 and 18-20. The model fits to the TLL indices showed that although all the indices could show a good fit in general to the TLL index in their fully integrated model, it could not achieve that in the ASPMR-fix model except the age 6-8 and age 18-20 indices (Fig. 5). Those indicated that the TLL VAST indices for age 6-8 and age 18-20 has a consistency with the current PBF assessment model.

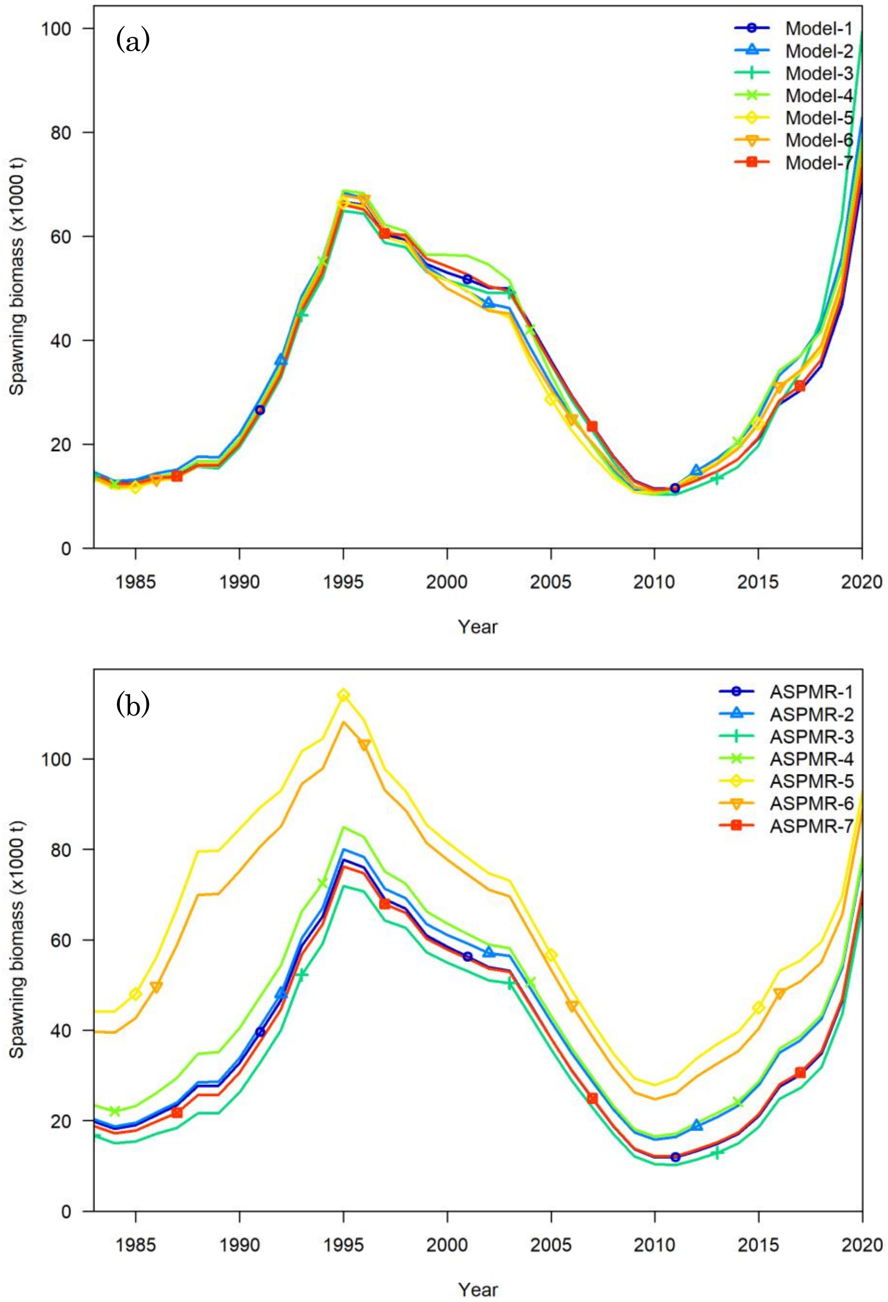

Figure 2 Estimated spawning stock biomass of Pacific bluefin tuna using the fully integrated model (a) and the age structured production model with fixed recruitment variation (b).

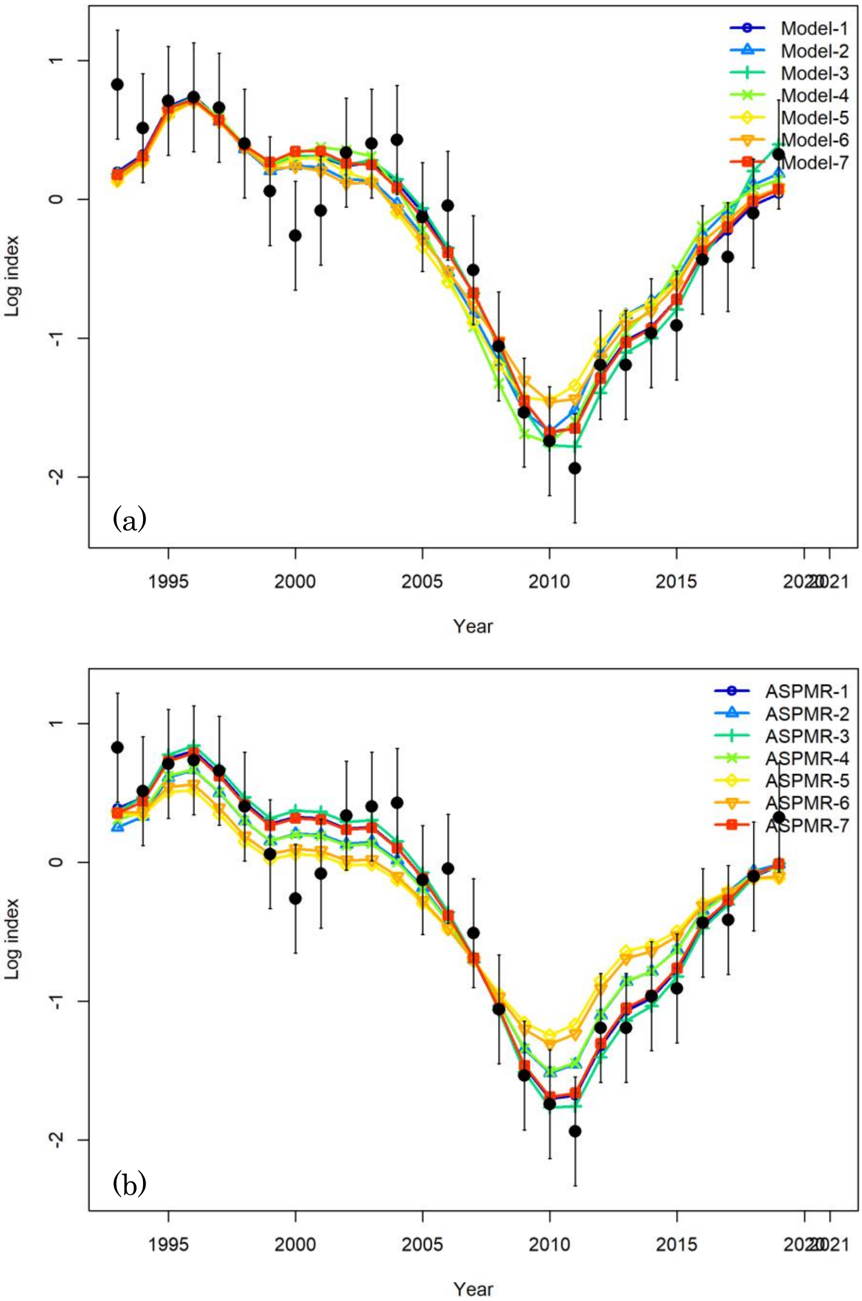

Figure 3 Observed (closed marker with vertical line) and predicted abundance index based on the Japanese longline CPUE (S1) for the Pacific bluefin tuna stock assessment models using the fully integrated model (a) and the age structured production model with fixed recruitment variation (b).

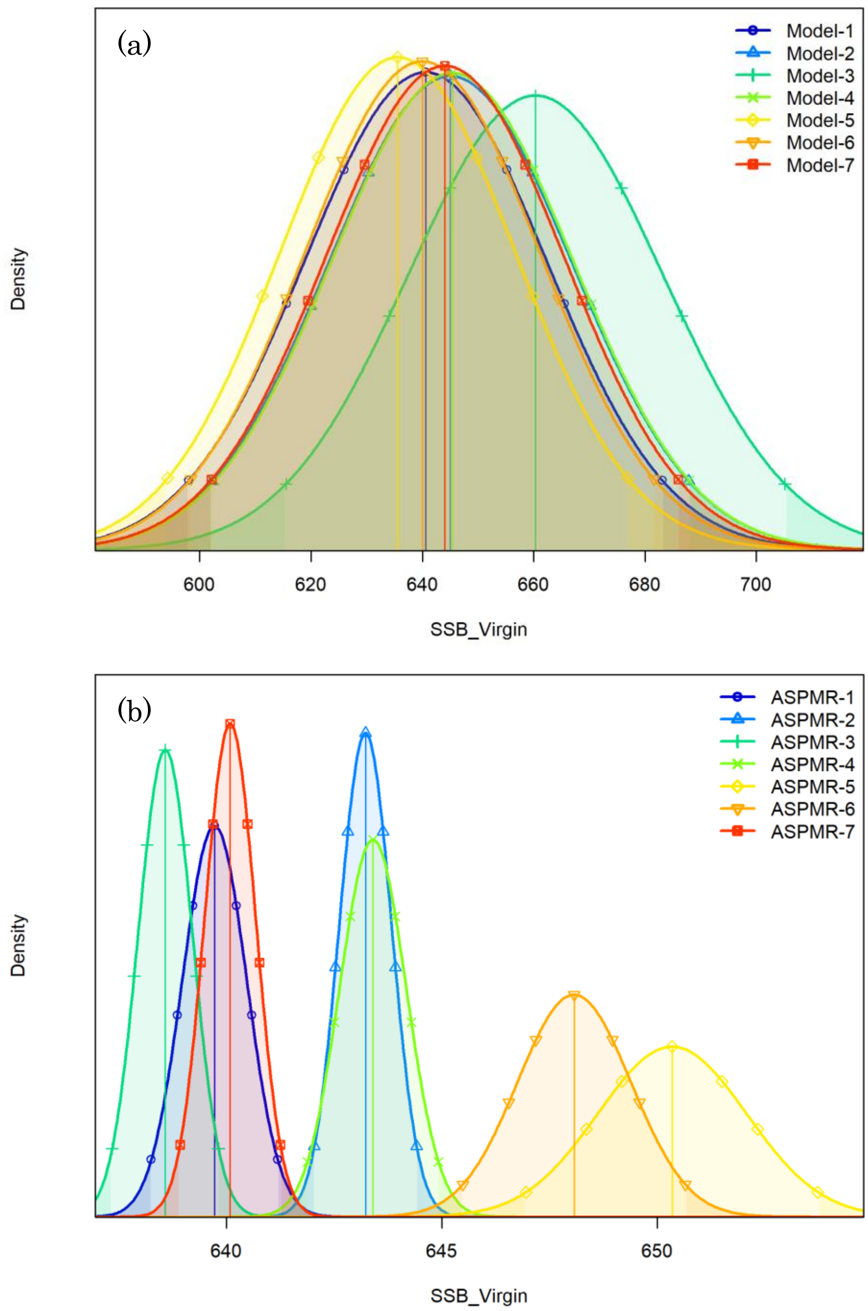

Figure 4 Density distribution of the unfished spawning stock biomass (SSB0) of Pacific bluefin tuna estimated using the fully integrated model (a) and the age structured production model with fixed recruitment variation (b).

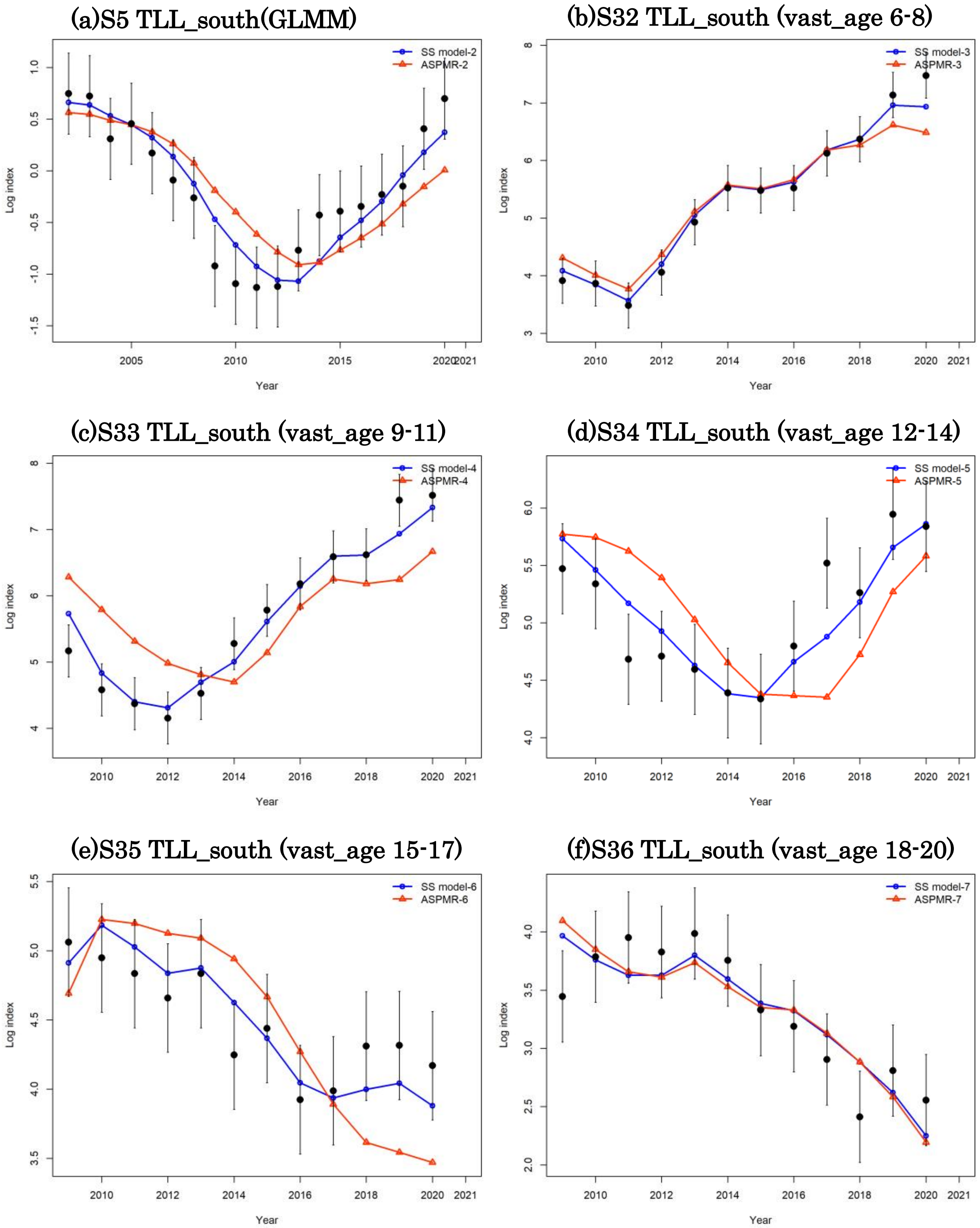

Figure 5 Observed and predicted Taiwanese longline CPUE based index for tested models by different model structure.

The estimated population scale was really similar among the ASPMR$_{fix}$-1, ASPMR$_{fix}$-3, ASPMR$_{fix}$-7 (Fig. 4b). This showed that those models with different abundance indices in the model reached to the same answer about the population scale.

2.) Retrospective analysis on the short-term model

After confirming the above results of ASPM+R$_{fix}$ diagnostics, retrospective analysis using a fully integrated SS model for the model-1, model-3, and model-7 were conducted (Fig. 6). It showed that the model fitted to the TLL-VAST-index for age 6-8 (model-3) did not show a clear retrospective bias as well as the model-1 which did not include TLL index in the model (Fig. 6b). The model-7 showed more obvious pattern of the underestimation (Fig. 6c).

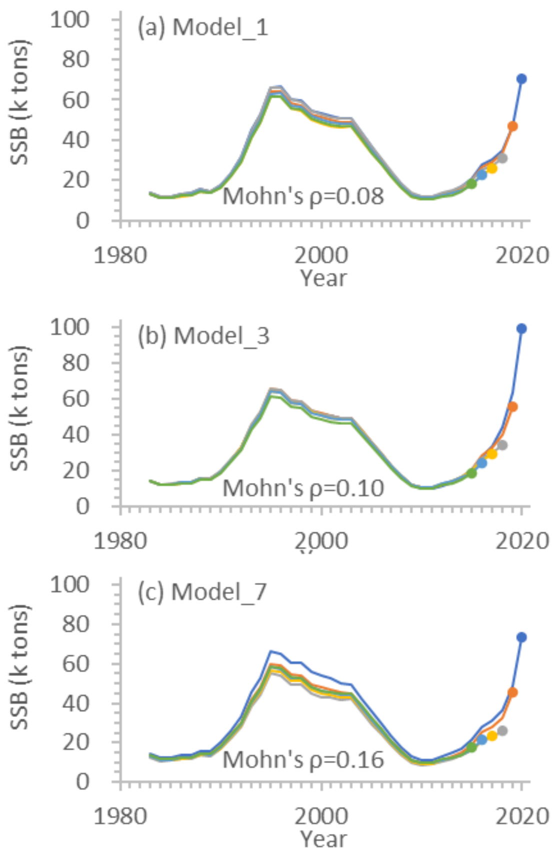

Figure 6 Five-year retrospective analysis on the PBF short-term models with an alternative assumption for TLL index of abundance.

4 Discussion and conclusion

This document provided several tests to confirm a consistency between the newly developed index of abundance based on the Taiwanese longline CPUE. The results indicated that the Model-3, which was fitted to the TLL spatio-temporal VAST-index for age 6-8 was the most consistent index with the current PBF short-term model. The results suggested that this index would have a similar information about the population scale with the current PBF model (Fig. 4d), and it can provide a future trend of the young adult population, which could not be possible using the Japanese longline CPUE based index.

The model-7, which was fitted to the TLL VAST-index for age 18-20 also showed a high consistency with the current PBF model, although it showed a degraded retrospective pattern than the Model-1 (Fig. 6). Since a current TLL VAST-index for age 18-20 showed a one-way decreasing trend of the oldest fish (Fig. 5f), it might be easier for the model fitting to this index than the rest of the indices, which had some contrast in its time series.

It should be noted that as the current TLL-VAST-index has only a short-timeseries (2009-2020 Fishing year), updates of the index could change the overall trend. The WG should be careful if they move to the VAST index with consideration of size (age) data from the traditional GLMM index. It might be better to further test for the Taiwanese longline VAST index at the next assessment meeting in March 2024. Now, there was a choice for the PBFWG about the Taiwanese longline CPUE based index;

1). Continuing to use the traditional GLMM index (live with some unstability);

2). Move to the spatio-temporal index incorporated size information.

The author recommended to move to the spatio-temporal index since it was theoretically sounds to incorporate the possible change in catchability and selectivity due to the recent change in the fishing ground. The results of this document basically supported this idea.

5 Literature cited

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