Is age-0 index unnecessary for the Pacific Bluefin tuna assessment?

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1 Introduction

Fukuda (2023) found the possible reasons of the systematic retrospective pattern shown in the 2022 PBF stock assessment base case (ISC 2022), and it suggested that the recruitment index based on the Japanese conventional troll CPUE (Nishikawa et al., 2020), in particular that of after 2010, might be one of the major causes. It reported that the conventional troll index in recent year informed to the model a declining trend of the SSB after 2015, and that information conflicted with the trend of the spawner indices based on the longline CPUEs, which showed an increasing trend since early 2010's. The Japanese conventional troll CPUE was the long time series dating from 1980. Nishikawa et al. (2021) reported a possible data bias of that index after 2016 due to the lack of information about live-release of small PBF or any other possible operational change. Because the data source of this index is the sales-slip, which did not include detailed information about the operation or zero-catch, it should be difficult to consider the changes in their fishery operation.

The model diagnostics shown in Fukuda (2023) suggested an advantage to exclude the recruitment index from the assessment model. It also showed that a model, which was not fitted to the recruitment index as well as the Taiwanese longline (TLL) index could output a similar trend of the SSB without any systematic retrospective pattern. Although the model which excluded the recruitment index and TLL index worked well, in the context of the benchmark stock assessment in 2024, it is desirable to understand more closely what occurred in the model by removing/adding the data from the previous base case model.

In this document, multiple model diagnostics were conducted to highlight the major changes occurred by removing/adding the recruitment index. We also tried to provide the expectable performance of the alternative recruitment index, which was based on the Japanese recruitment monitoring survey (Fujioka et al., 2021). The purpose of this document was to provide a recommendable data-set regarding the recruitment index for the next assessment.

2 Model and Data

A modified version of the short 2022 Stock Synthesis (SS) (Methotand Wetzel, 2013) PBF stock assessment model (Fukuda et al. 2021) was used for the basis of analysis. Five models of different combination of the abundance indices were prepared for comparison;

1.) Only Japanese longline (JLL) indices (1983-1992, 1993-2019 FY) in the model;
2.) Japanese longline indices (1983-1992 FY, 1993-2019 FY) and the conventional troll recruitment index (1980-2016) in the model;

3.) Japanese longline indices (1983-1992 FY, 1993-2019 FY) and the conventional troll recruitment index (1980-2010) in the model;
4.) Japanese longline indices (1983-1992 FY, 1993-2019 FY), the conventional troll recruitment index (1980-2010), and Japanese recruitment monitoring index (2011-2020) in the model;
5.) Japanese longline indices (1983-1992 FY, 1993-2019 FY), the conventional troll recruitment index (1980-2010), and Japanese recruitment monitoring index (2017-2020) in the model.

In accordance with the results of Fukuda (2023), which showed an instability of the estimated SSB by the model fitted to the TLL index, TLL index was not used in above models. This issue will be discussed in another document submitted to the November 2023 PBFWG meeting. The catch time series and size composition data were common among the models. A list of the model configuration was shown in Table 1.

On those models, a retrospective analysis, an age structured production model with recruitment deviation (ASPM+R), and a likelihood profile over the scaling parameter (log R0) were performed. The retrospective analysis in this document was an examination of the recruitment index used/not in the model to understand consistency of the tested index with other data sources and identify potential bias given by the recruitment index. A higher absolute value of Mohn's rho than the Model 1 (no recruitment index in the model) would be an indication of the biased information given by the recruitment index.

The ASPM+R analysis in this document was performed to closely identify the source of information to estimate recruitment deviation parameters. Two types of the ASPM+R, the one estimates the recruitment deviation (ASPM+R_{est}) and the another was fixed recruitment deviation at the estimated values by the fully integrated model under each data structure (ASPM+R_{fix}), were performed. An ASPM+R_{fix} could evaluate the consistency of the recruitment information given by the data with the adult abundance index, not through the negative log likelihood summed up for the residuals of the data. A degraded fit to the adult abundance index than the model-1 (no recruitment index in the model) was an indication of the data conflict between the adult abundance index and the tested recruitment index. An ASPM+R_{fix} on the model-1 (no recruitment index in the model) might be able to show a potential consistency of the recruitment information given by the size composition data with the adult abundance index. An ASPM+R_{est} in this document was performed to show the consistency of the recruitment estimates under the data structure of each ASPM+R_{est} with the fully integrated model, which is the most "information-rich" model. By design of ASPM+R_{est}, which has less restrictions for recruitment estimation due to less observed data, this model naturally could show a better fit to the adult abundance index than the fully integrated model. However, discrepancies from the recruitment estimates by the fully integrated model could be an indication of the over-fitting of the model to the adult index in that model by compensating the recruitment to make a better fit to the adult index.

3 Results

1.) Comparisons among the models

Time series of the SSB and Recruitment estimated using all available data (fully integrated model) were shown in Fig. 1a and 1b for all models. The SSB estimates were similar among the models except model-4, which fitted to the recruitment monitoring index for 2011 to 2020. The recent recruitments estimated by the model-4 were higher than the rest of models and it would result a higher terminal SSB than others (Fig. 1a). Estimated population scale (SSB_0) were basically consistent between 620 and 660 hundred thousand tons (Fig. 5).

2.) Retrospective analysis

As shown in Fukuda (2023), the model fitted only to the JLL index (model-1) did not show a systematic retrospective pattern, but the model fitted to the recruitment index during 1983 to 2016 FY (model-2) showed a systematic pattern (Fig. 6a, b). The model-3, which fitted to the recruitment index in the early to middle period (1983-2010 FY), showed a similar result on the retrospective analysis with the model-1. The models which fitted to the recruitment monitoring index (models-4 and 5), also did not show a clear pattern of retrospective error (Fig. 6d and 6e).

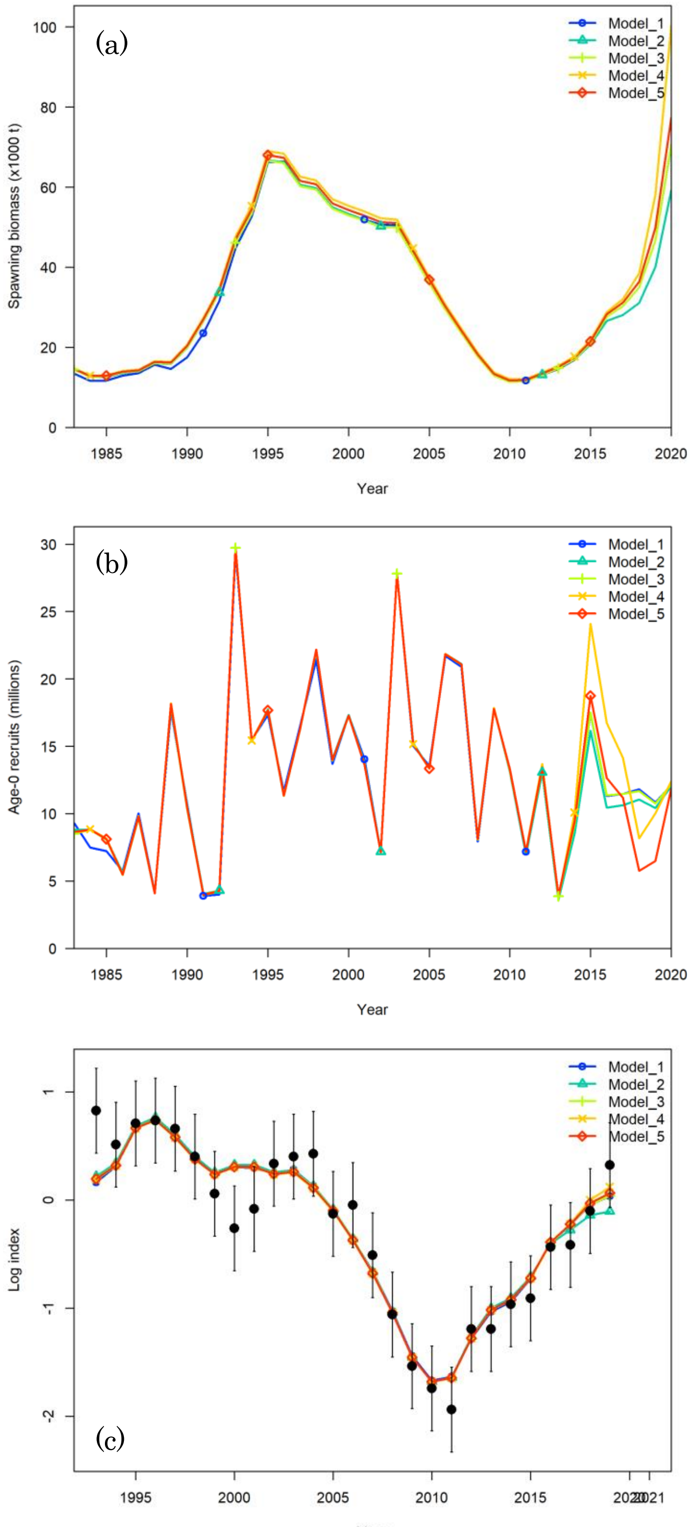

Figure 1 Estimated Spawning Stock Biomass (Top), Recruitment (middle), and the observed (closed circle with an error bar) and predicted abundance index from Japanese longline fleet (Bottom) by the fully integrated models for different data structures about the recruitment index.

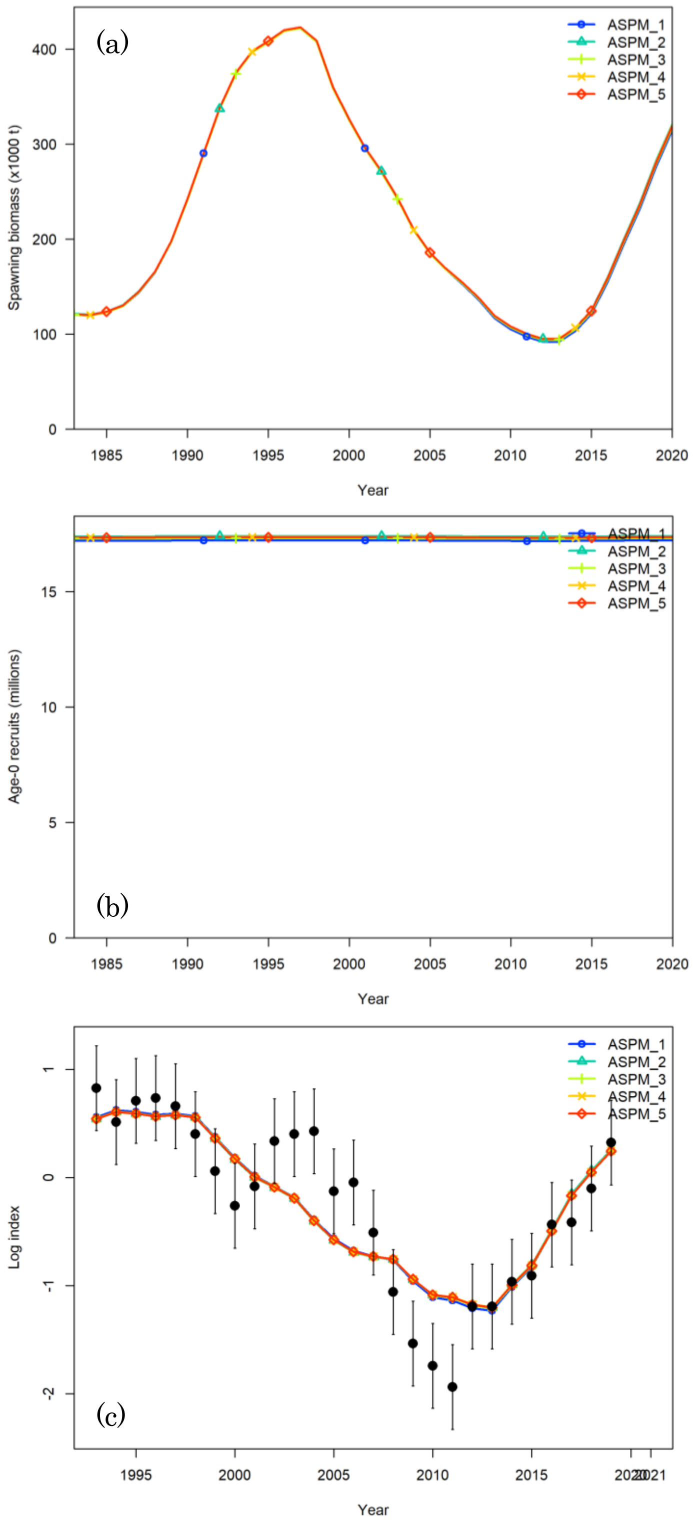

Figure 2 Estimated Spawning Stock Biomass (Top), Recruitment (middle), and the observed (closed circle with an error bar) and predicted abundance index from Japanese longline fleet (Bottom) by the Age Structured Production Models for different data structures about the recruitment index.

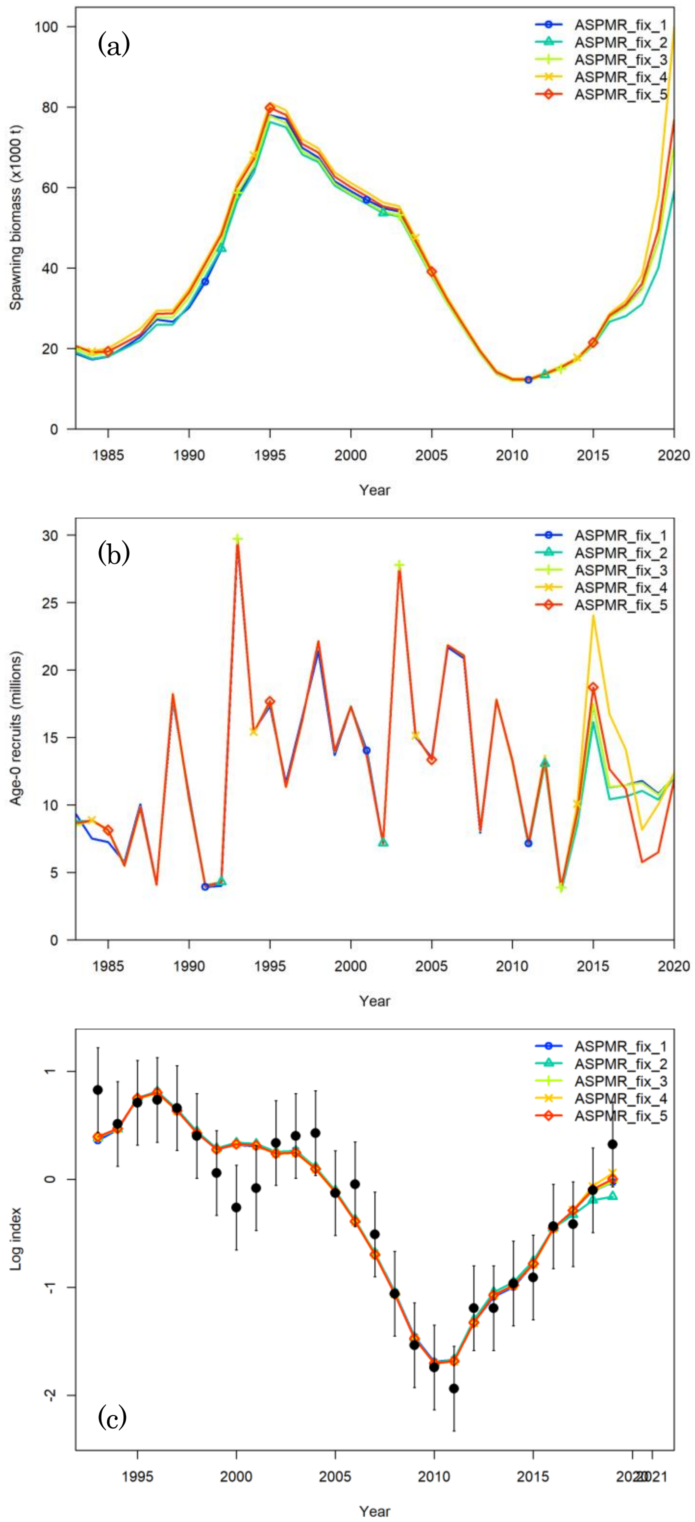

Figure 3 Estimated Spawning Stock Biomass (Top), Recruitment (middle), and the observed (closed circle with an error bar) and predicted abundance index from Japanese longline fleet (Bottom) by the Age Structured Production Models with fixed recruitment deviations for different data structures about the recruitment index.

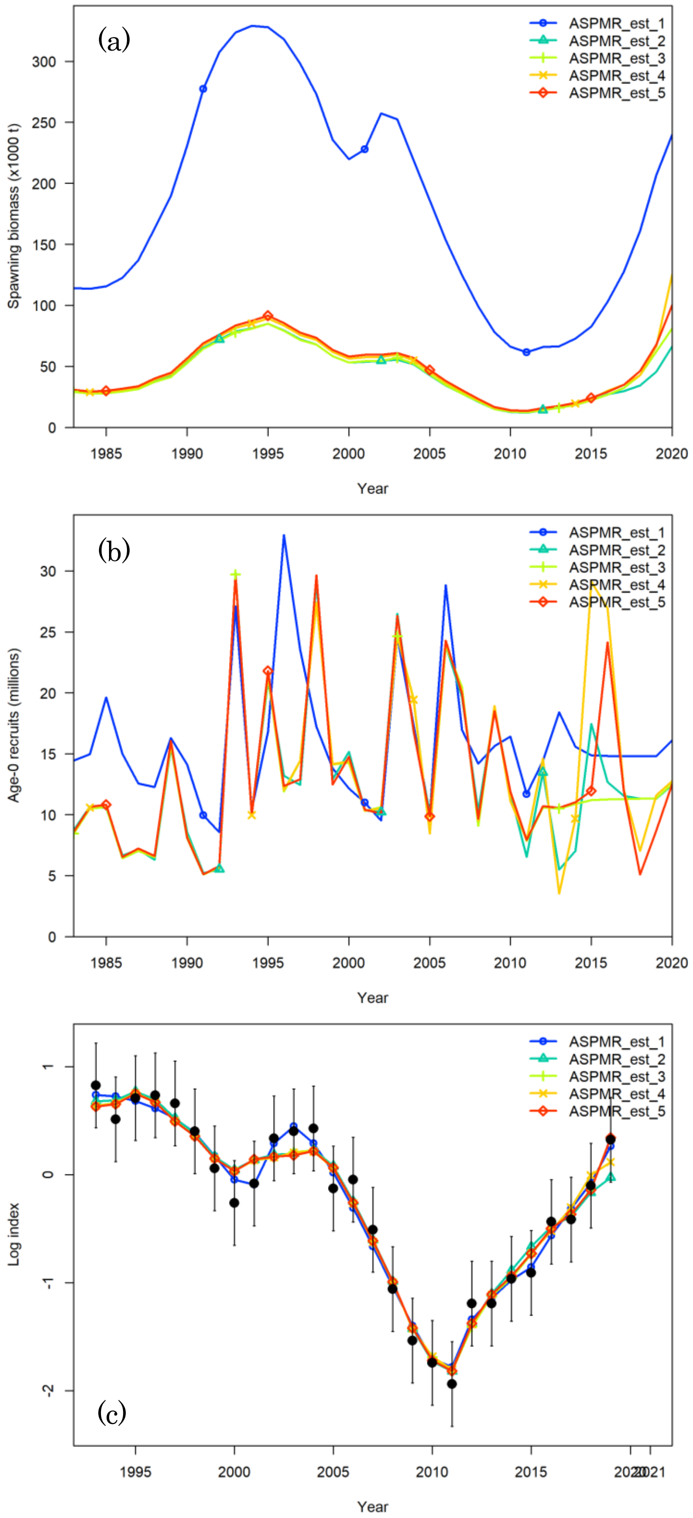

Figure 4 Estimated Spawning Stock Biomass (Top), Recruitment (middle), and the observed (closed circle with an error bar) and predicted abundance index from Japanese longline fleet (Bottom) by the Age Structured Production Models with estimated recruitment deviations for different data structures about the recruitment index.

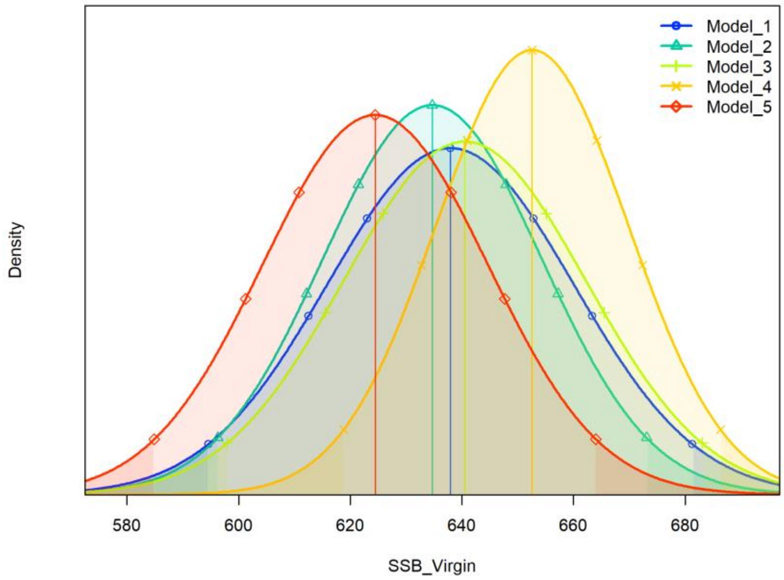

Figure 5 Density distributions of the estimated population scale (SSB0) by the PBF short term models with alternative data structure for the recruitment index.

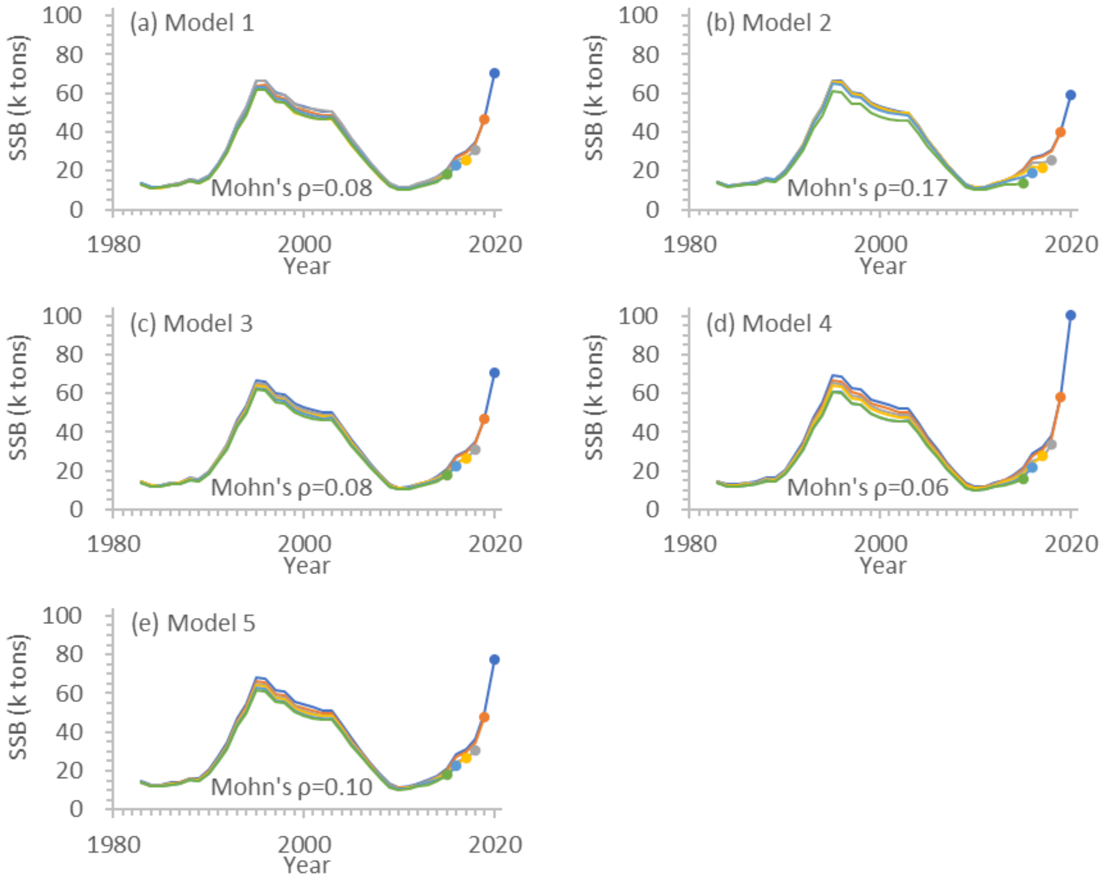

Figure 6 Five-year retrospective analysis on the PBF short-term models with an alternative data structure for the recruitment index.

3.) ASPM+R_{fix} and ASPM+R_{est}

The ASPMs for the models 1-5 could depict the general trend of the abundance index of the large adult (Fig. 2c). The ASPM+R_{fix} showed a better fit to the S1 index than those by the ASPMs. Those models also showed a general low RMSE values for the recruitment index (RMSE < 0.22; Table 2) although those models were not fitted to the recruitment index. Those indicated a general consistency of the recruitment information derived by the recruitment index (maybe and size composition data) with the adult abundance index. However, among those runs, ASPM+R_{fix} using an information from the recruitment index during 1983-2016 showed a higher RMSE value for the adult index than the rest of the ASPM+R_{fix} (Table 2), and this run predicted a lower adult index than the observed index for a couple of terminal years (Fig. 3c). This would be another indication of the biased information derived by the recruitment index in recent years.

The ASPM+R_{est} showed a very good fit to the adult abundance index (Fig. 4c, Table 2). They also showed a very good fit to the recruitment index except the ASPM+R_{est}-1 which did not include the recruitment index in the model. The estimated recruitments by ASPM+R_{est}-1 differed from the rest of the models and the level of the SSB also deviated (Fig. 4a & 4b). Since the ASPM+R_{est}-1 did not include the composition data and recruitment index in the model, this model would not be able to estimate the recruitment correctly. Instead, the ASPM+R_{est}-1 showed the best fit to the adult abundance index (Fig. 4c and Table 2) among all of the runs, however, this might be an overfitting to the observed data by compensating the recruitment to shape the SSB matching to the adult index.

4 Discussion

1.) Observed data to estimate the historical recruitment

This document showed a strong consistency among the catch, composition data, and the index of abundance for both the adult and recruitment for the historical period (1983-2010). However, the model-2, which included the Japanese troll recruitment index up to 2016, showed slightly degraded fit to the adult abundance index on ASPM+R_{fix} analysis. The model-1 (no recruitment index in the model) and 3 (recruitment index was included during 1983-2010) showed a similar model performance on the retrospective analysis, ASPM, and ASPM+R_{fix}. However, the ASPM+R_{est} of the model-1 showed deviated SSB and recruitment from those of the fully integrated model. Since the model-1 rely on the composition data to estimate the recruitment, ASPM+R_{est}-1, which excludes the size data from the model, could not estimate the recruitment correctly.

The size composition data theoretically have information regarding the cohort strength, and that could inform the assessment model under the correct specification of the selectivity and data weighting. Fortunately, current PBF assessment model showed a consistency of information between the size composition and recruitment index at least prior 2010, and the recruitments estimated by the ASPM+R_{fix} of the model-1 were similar with the current assessment results. The recruitment index before 2010 seemed like a sundial in the shade and it did not show up unless the size composition data were excluded from the model. However, a high dependence on the size composition data for abundance estimates could lead an instability of the model to the alternative data weighting or selectivity setting. Since there was a confirmed internal consistency among the recruitment index and adult abundance index in the model, the authors recommended to include recruitment index in the model.

2.) Observed data to estimate the recent recruitment

There were differences in the observation models among the model-3 to model-5 regarding the usage of the recruitment monitoring survey index. The authors had anticipated to evaluate the advantage (and disadvantage) to use this survey index through the ASPM-R_{fix} analysis. However, the results were similar among those models given a short time series of the recruitment monitoring index. A faint sign was shown in lower RMSE values for JLL index in the ASPM+R_{fix}-4 and ASPM+R_{fix}-5 than that of the ASPM+R_{fix}-3, but it was really hard to see in Figure 3c. A consideration about the usage of the most recent recruitment index is crucially important because it could be advantageous for the PBF assessment as well as the short-term projection if the information derived by the index is correct. This issue should be conveyed to the assessment meeting in March 2024 with the most recent time series of data.

5 General Conclusion

This document provided both of advantage and disadvantage to exclude the recruitment index from the model (Model-1). This could give a more consistent, but information-poor model. On the other hand, a model using the recruitment index during

1983-2010 (Model-3) did not bring a conflict between the recruitment index and adult index, while it could estimate the recruitment stably with a consistent information regarding the cohort strength. Exclusion of the recruitment index during 2011-2016 from the previous assessment was basically supported by both of the retrospective analysis and ASPM+R analysis.

Although there was limited background information that explains the temporal inconsistency of the conventional troll CPUE-based recruitment index before and after 2010, the first implementation of the fishery management lead by the ministry was announced in May 2010, and a registration system of the coastal troll vessel to reduce the catch of small size PBF started in 2011 (FRA, 2010). This kind of management action, maybe in conjunction with an increasing oil price and/or aging of fishermen, might affected to the catchability of the conventional troll. Also, since the conventional troll index is the long time series dating from 1980, a constant catchability throughout the period might be a stretch assumption even though it was standardized CPUE. As a conclusion of the document, the authors recommended to exclude the conventional troll CPUE index during 2011-2016 and to remain that index during 1983-2010 in the model. The usage of the recruitment monitoring survey index after 2011 as an alternative for the conventional troll index was an important issue for the PBF stock assessment, but this issue should be further discussed at the stock assessment meeting in March 2024 with the most recent time series data.

6 Literature cited

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Table 1 Data structure and model parameter setting for the short-term model and alternative models.

	Data fitted in the model					Parameter estimated/fixed			
	Catch	Size	JLL index	TLL index	Age-0 index	Log R_0	Initial F	Rdev	Selectivity
Model-1	Yes	Yes	Yes	No	No	Estimated	Estimated	Estimated	Estimated
Model-2	Yes	Yes	Yes	No	S4 (to 2016)	Estimated	Estimated	Estimated	Estimated
Model-3	Yes	Yes	Yes	No	S4 (to 2010)	Estimated	Estimated	Estimated	Estimated
Model-4	Yes	Yes	Yes	No	S4 (to 2010) S12 (2011-2020)	Estimated	Estimated	Estimated	Estimated
Model-5	Yes	Yes	Yes	No	S4 (to 2010) S13 (2017-2020)	Estimated	Estimated	Estimated	Estimated
ASPM-1	Yes	No	Yes	No	No	Estimated	Estimated	none	fixed at Mod-1 value
ASPM-2	Yes	No	Yes	No	No	Estimated	Estimated	none	fixed at Mod-2 value
ASPM-3	Yes	No	Yes	No	No	Estimated	Estimated	none	fixed at Mod-3 value
ASPM-4	Yes	No	Yes	No	No	Estimated	Estimated	none	fixed at Mod-4 value
ASPM-5	Yes	No	Yes	No	No	Estimated	Estimated	none	fixed at Mod-5 value
$ASPMR_{fix}$-1	Yes	No	Yes	No	No	Estimated	Estimated	fixed at Mod-1 value	fixed at Mod-1 value
$ASPMR_{fix}$-2	Yes	No	Yes	No	No	Estimated	Estimated	fixed at Mod-2 value	fixed at Mod-2 value
$ASPMR_{fix}$-3	Yes	No	Yes	No	No	Estimated	Estimated	fixed at Mod-3 value	fixed at Mod-3 value
$ASPMR_{fix}$-4	Yes	No	Yes	No	No	Estimated	Estimated	fixed at Mod-4 value	fixed at Mod-4 value
$ASPMR_{fix}$-5	Yes	No	Yes	No	No	Estimated	Estimated	fixed at Mod-5 value	fixed at Mod-5 value
$ASPMR_{est}$-1	Yes	No	Yes	No	No	Estimated	Estimated	Estimated	fixed at Mod-1 value
$ASPMR_{est}$-2	Yes	No	Yes	No	S4 (to 2016)	Estimated	Estimated	Estimated	fixed at Mod-2 value
$ASPMR_{est}$-3	Yes	No	Yes	No	S4 (to 2010)	Estimated	Estimated	Estimated	fixed at Mod-3 value
$ASPMR_{est}$-4	Yes	No	Yes	No	S4 (to 2010) S12 (2011-2020)	Estimated	Estimated	Estimated	fixed at Mod-4 value
$ASPMR_{est}$-5	Yes	No	Yes	No	S4 (to 2010) S13 (2017-2020)	Estimated	Estimated	Estimated	fixed at Mod-5 value

Table 2 Estimated unfished recruitment (R0), Root Mean Square Error (RMSE) for model fit to the index of abundance for the short-term model and alternative models. The RMSE for the recruitment index was calculated for the period 1983-2010 for all models.

	R0	RMSE for JLL index	RMSE for Recruit index
Model-1	13,580	0.237	0.224
Model-2	13,511	0.242	0.187
Model-3	13,635	0.235	0.184
Model-4	13,892	0.234	0.182
Model-5	13,293	0.235	0.183
ASPM-1	17,221	0.378	0.499
ASPM-2	17,408	0.386	0.476
ASPM-3	17,312	0.384	0.473
ASPM-4	17,367	0.386	0.468
ASPM-5	17,361	0.385	0.470
$ASPMR_{fix}$-1	13,563	0.219	0.217
$ASPMR_{fix}$-2	13,497	0.231	0.182
$ASPMR_{fix}$-3	13,616	0.219	0.179
$ASPMR_{fix}$-4	13,872	0.216	0.177
$ASPMR_{fix}$-5	13,275	0.218	0.177
$ASPMR_{est}$-1	18,034	0.120	0.484
$ASPMR_{est}$-2	13,954	0.161	0.144
$ASPMR_{est}$-3	14,033	0.144	0.138
$ASPMR_{est}$-4	14,295	0.153	0.137
$ASPMR_{est}$-5	14,039	0.145	0.138