Reinforcement of Japanese PBF Recruitment Monitoring Program

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1. Introduction

As described in Nishikawa et al. (2021), the recent fishery management for the recovery of the Pacific bluefin tuna (PBF, *Thunnus orientalis*) stock affected to the number of operations, fishing season, operational purpose (for farming/market), catch allocation to each vessel (Individual Quota or Area-based Quota), and frequency of the live-release by the Japanese troll fishery. Those operational changes could change the catchability of this fishery, however, some of them were not recorded in the sales slip, which is the data sauce of the Japanese conventional troll CPUE. The possible variation or bias of the catchability due to the operational change should have been considered in the process of the CPUE standardization, however, the current data source cannot allow it. Since an informative index of recruitment by the Japanese conventional troll index (Survey 4 in the model) is the one of the biggest advantages for the PBF assessment, an alternative plan should be considered if the S4 index is not suitable for the future assessment.

In the PBF assessment, one of the key features is the internal consistency of the information from the recruitment to their reproduction which were informed by the recruitment and adult indices, catch, and size composition data given the assumption of the population dynamics. Because of the high consistency among the model and data, the model could estimate reasonably similar recruitments even without the S4 index, except the recent couples of recruitments (Kumegai et al., 2015). Among the data, only the S4 index could inform to the model about strength of the most recent recruitment. Among the past several assessments conducted in the 2016, 2018, and 2020, the recruitment estimates were almost identical when they are overlapped including the terminal year of each assessment (Fig. 1). Since PBF were caught from age-0, the reliable estimates of the recruitment and fishing mortality for the terminal year are necessary for the future projection, which is used to consider the management action in the RFMOs. Those suggested that an alternative index of recruitment is necessary for the PBF assessment to provide a reliable management advice.

In this document, we listed some candidates of an alternative indices to inform the relative strength of PBF recruitments. We also provided a research project of Japan Fisheries Research and Education Agency (FRA), to strengthen the monitorability of PBF recruitment. The expectable performance of the alternative index was discussed.

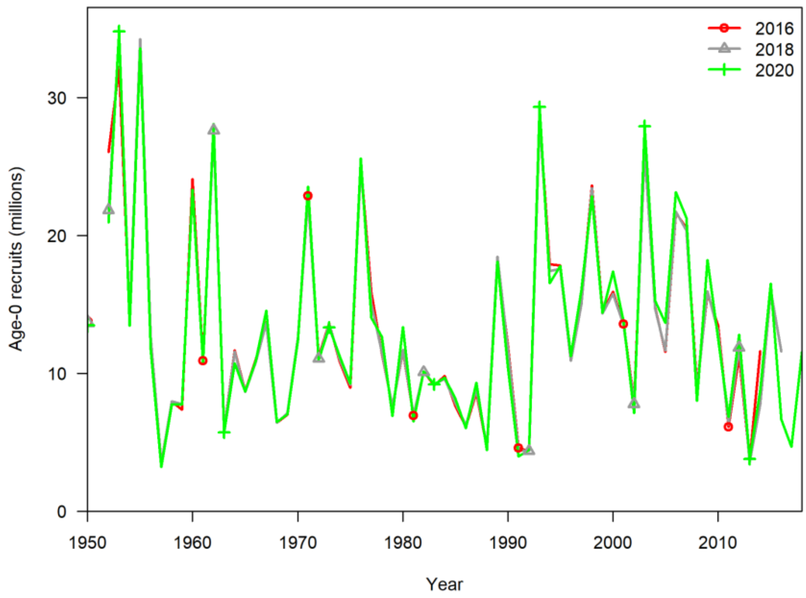

Fig. 1 Comparisons of the recruitment estimates among the assessments conducted by the ISC in 2016 (red), 2018 (grey), and 2020 (green).

2. Candidates of the alternative recruitment index

2.1 CPUE based index from Fisheries besides Japanese Troll

In the past ISC PBFWG meetings, several indices had been presented as the potential input data for the stock assessment (Table 1). The most of them are based on the fishery data (CPUE based index) but not from the Japanese troll fishery. Given the current assessment schedule, which has the assessment meeting in February or March using data up until June of the previous year, the age-0 index is required to inform the terminal year's recruitment to the model. However, only Japanese troll fishery caught age-0 PBF as their main target and the rest of the indices are from fisheries catching PBF of the migratory ages (ages of PBF when they migrates trans-

Pacific widely; c.a. ages 1 to 5). The age-1 index can inform the relative strength of the second terminal year but not for the latest year in the current schedule.

Also, the temporal variation in the size composition data for the listed fisheries except Japanese troll would indicate the mixed effect of the recruitment variation, different fishing mortality to each cohort, and possible age specific migration. Since the current assessment model does not have the explicit spatial structure, the index used in the model should not be affected by the migration.

In the latest assessment model, some of the listed indices shows somewhat good compatibility with the model predictions (e.g. Kor PS index (Survey 10), Fig. 2), however, above two issues still suggested to use the age-0 index for the assessment.

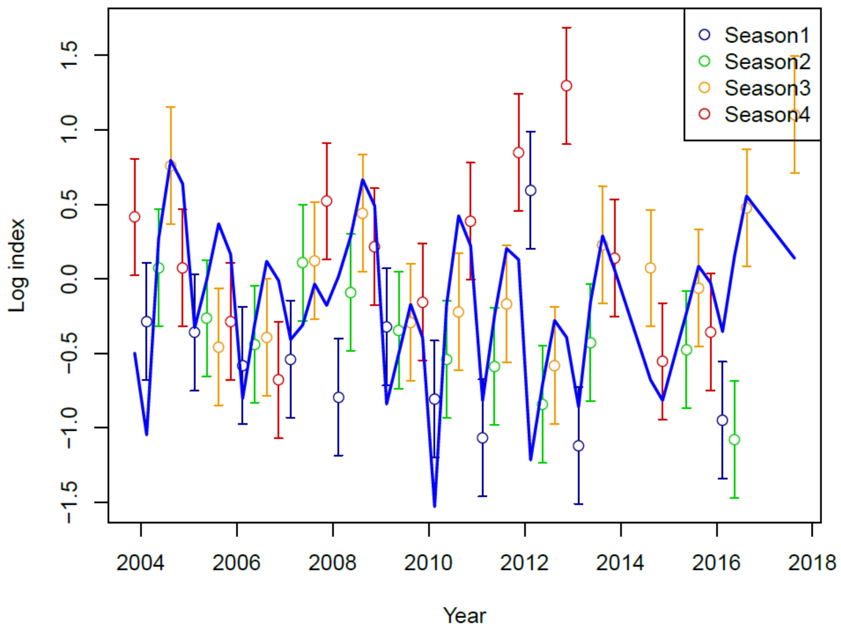

Fig. 2 Observed KOLPS CPUE based index (Survey 10; circle with error bar) and the predicted value (blue solid line) by the 2020 stock assessment model.

2.2 CPUE based index from the Japanese Troll fishery

Besides the index from Japanese conventional troll fishery, we have two Japanese troll real-time monitoring indices. Those basically monitored the same troll fishery operated in the East China Sea (Survey 12; Winter index) or in the ECS and the Pacific coast of western Japan (Survey 11; Summer index). In the summer operation, Japanese troll fishery targets age-0 PBF of smaller than 50 cm FL (Fig. 3), which is empirically considered to be born in the North Western Pacific Ocean (around Taiwan and Nansei islands). In the winter operation at the ECS, the troll fishery caught around 40-60 cm PBF (Fig. 4), which would be born in both of main spawning grounds, namely the NWPO and the Sea of Japan. Data of the real-time monitoring survey index in winter were collected from the same season and area with the conventional troll index, so that the winter index could conceptually have higher similarity with the conventional troll index than the summer index.

In the 2020 PBF stock assessment, those real-time monitoring indices were also included in the model (Survey 11: Summer index, Survey 12: Winter index), without fitting to the likelihood function, and they showed a compatibility with the assessment model predictions in particular prior to 2017, when little information or only the biased information about recruitment are available in the assessment model due to the lack of 2017 S4 index data point and a possibly biased 2018 S4 index data point.

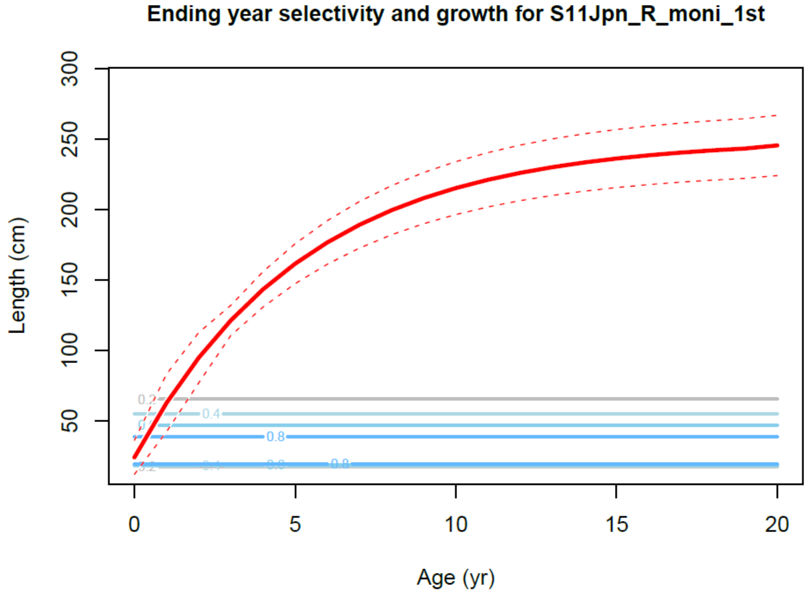

Fig. 3 Length at Age based on the von Bertalanffy growth function (Red solid line) with standard deviation (Red broken line), and the selectivity of troll fishery (Blue solid lines with probability in number) in the Fishery Season 1 (mid-August in Calendar).

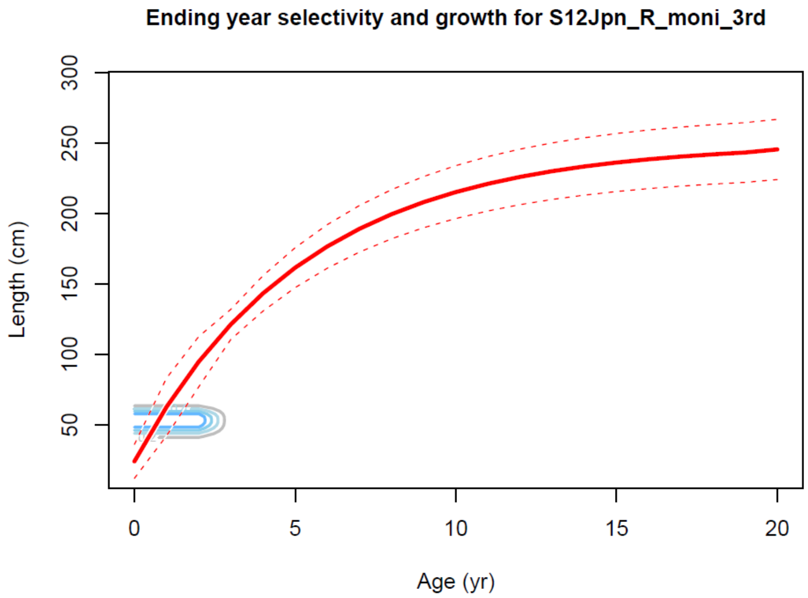

Fig. 4 Length at Age based on the von Bertalanffy growth function (Red solid line) with standard deviation (Red broken line), and the selectivity of troll fishery (Blue solid lines with probability in number) in the Fishery Season 3 (mid-November in Calendar).

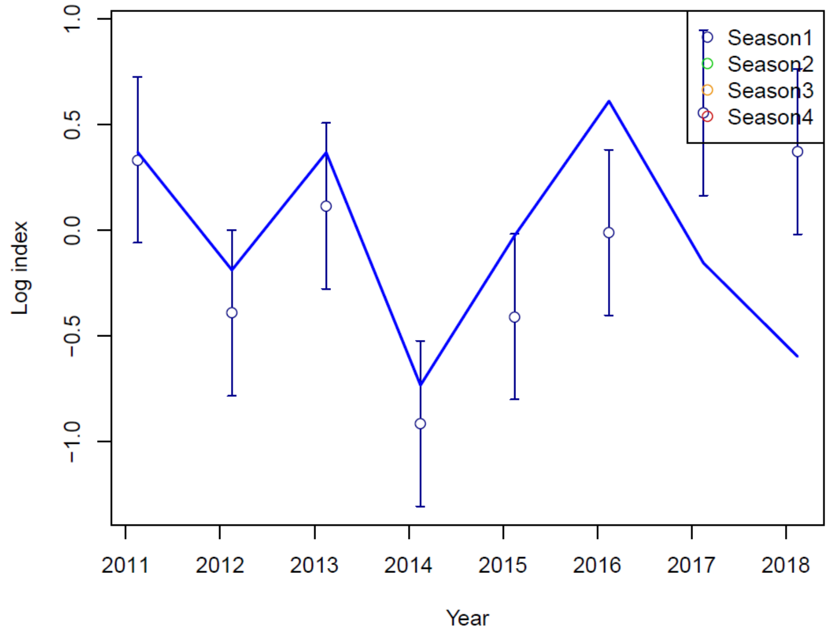

Fig. 5 Observed real-time monitoring in summer index (Survey 11; circle with error bar) and the predicted value (blue solid line) by the 2020 stock assessment model.

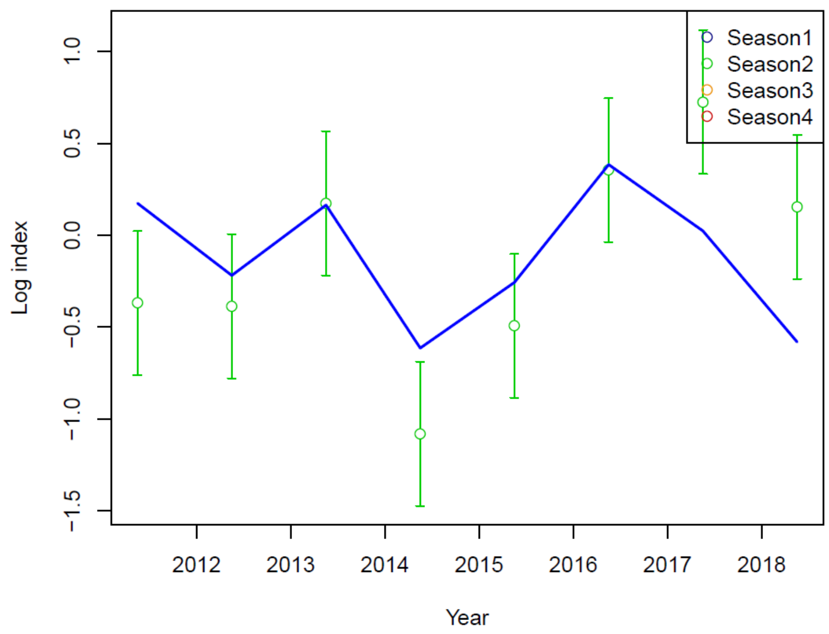

Fig. 6 Observed real-time monitoring in winter index (Survey 12; open circle with error bar) and the predicted value (blue solid line) by the 2020 stock assessment model.

3. Evaluation of performance of candidate Age-0 index

Age Structured Production Model with specified Recruitment variability based on the recruitment index (ASPM-R) analysis could be an approach to evaluate the performance of the candidate recruitment index objectively. For the comparisons, we prepared 3 ASPM-like models;

1.) Age Structured Production Model without recruitment deviation, which are fitted to the catch and adult indices (ASPM);

2.) ASPM with specified recruitment deviations, which are estimated by a preparation run with the conventional troll index without 2017-18 datapoints (ASPMR_S4);

3.) ASPM with specified recruitment deviations, which are estimated by a preparation run with the conventional troll index (1980-2010) and the real-time monitoring Winter index (2011-2016) (ASPMR_S12).

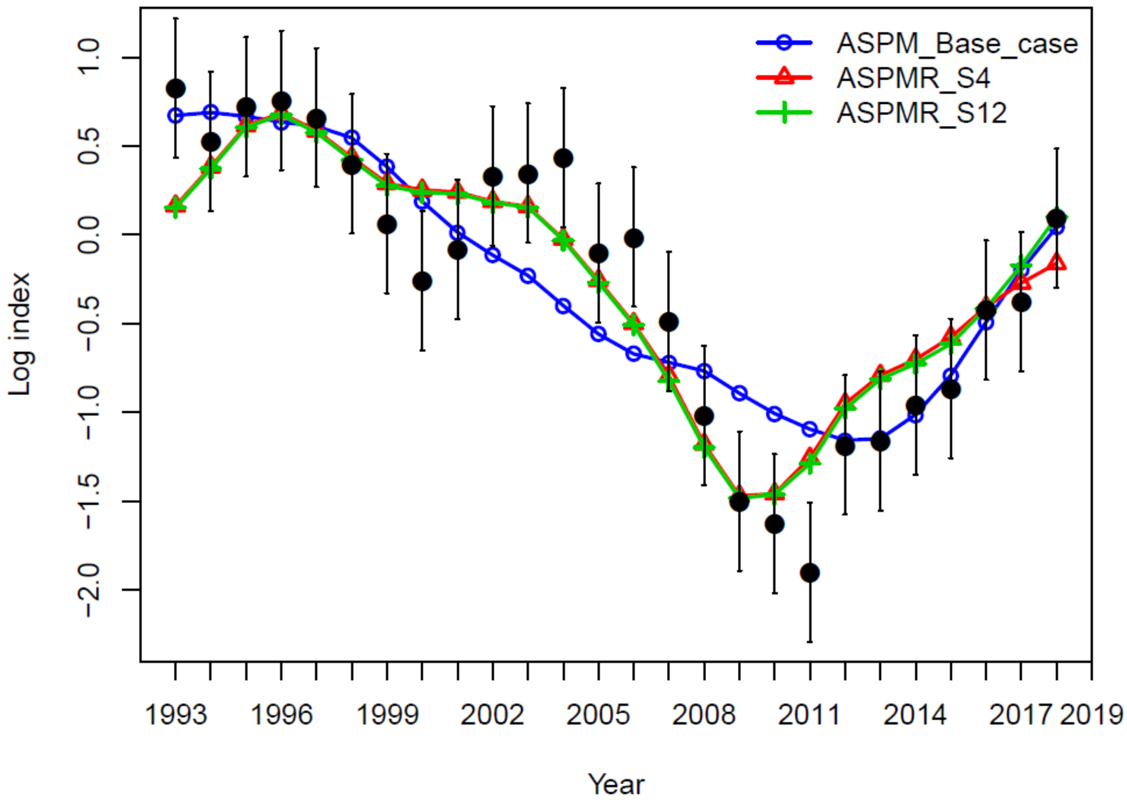

Fig. 7 Observed Japanese Longline index recent time series (Survey 1; closed circle with error bar) and the predicted values by ASPM (blue), ASPMR_S4 (red), and ASPMR_S12 (green), respectively.

Figure 7 shows the model fit to the terminal Japanese longline index by the ASPM and ASPM-R models. In here, all the models fitted to the same data series (catch and adult index), but ASPM-R models had an additional model process of recruitment variability based on the conventional troll and real-time troll monitoring indices, respectively. The recruitment deviations are not estimated but specified, thus those recruitment variations are not the data but assumption now. If the recruitment process is well specified, the model fit to the reliable biomass index (e.g. longline indices) will be improved.

Both of the ASPM-R models showed improved model fit to the terminal Japanese longline index. In terms of the last few years, The ASPM-R based on the real-time monitoring index showed slightly better fit to the adult index. This result suggested that the Japanese real-time monitoring index also could inform the recruitment variability to the model with maintaining the consistency of information among the other indices.

4. Reinforcement of Japanese recruitment monitoring program for PBF

4.1 Data collection

As described by Nishikawa et al. (2021), there would be a considerable effect of the fishery managements for the data collection to estimate both of the conventional troll CPUE as well as real-time monitoring CPUE. Since the data source of the former index is the sales-slip data, a data bias due to the lack of information about live-release of small PBF, which are increased from 2017 due to the minimum size limit regulation, would be inevitable. On the other hand, the catch in number of PBF including the number of live-released PBF could be collected through the real-time troll monitoring survey. As a solution, FRA planned to reinforce the data collection framework through the real-time troll monitoring survey.

In the previous survey framework, a decreasing trend or the bias in the temporal variation in the troll operation due to the change in the operational purpose for the farming operation could be the biggest issue. Then, FRA has started a real-time monitoring survey of a chartered vessel in addition to the usual troll monitoring survey. For this additional survey, all of the real-time monitoring vessels will be chartered for 10 operational days, so that information of more than 100 operational days could be collected in addition to the usual operations. Those chartered operations will be independent from the fishery management by the national or local government, so the catch during the survey could be included as a part of the quota for research of FRA. Then, the chartered vessels do not take care about their IQ at lease during the chartered operations.

4.2 Data Analysis

Although the raw data of the real-time troll monitoring survey include spatial and temporal information in high resolution, the current CPUE standardization model did not fully utilize those information (e.g. catch number per day in area A or B). For the better representativeness of abundance and to reduce negative effect of spatial and temporal bias of the operation, we plan to predict the CPUE for each time (hour) and a spatial unit (square) with a consideration of the spatial and temporal correlation. This kind of approach (spatio-temporal standardization) is already introduced to the Japanese longline CPUE standardization for the PBF assessment and it demonstrated a advantage in the robustness to the data missing due to the temporal suspension by the fishery management.

5. Age-0 index for the future PBF assessment

Because there are evidence of the data bias and increase in the uncertainty in the conventional troll CPUE, we proposed to exclude this index from the future PBF assessment. As an alternative, we also propose the Japanese real-time monitoring index in the Winter operation, which shows similar performance with the conventional troll CPUE by the ASPM-R model diagnostics. The year in the model to switch the index from the conventional troll to the alternative index could be a decision-point and the authors invite the PBFWG for discussion. If the conventional troll index and an alternative index have similar (and reliable) information about the recruitment, it is possible to switch at earlier year (i.e. 2011 FY), then the terminal index time series could inform the model about the relative strength of recruitment in higher resolution. The WG may want to discuss this issue as well.

Table 1 List of the potential candidate recruitment indices

Fishery	Area	Age	Note
Jpn conventional Troll (S4)	East China Sea	Age 0 (Non-migratory age)	Index currently used for SA. Representative of two main spawning grounds.
Kor PS	East China Sea	Ages 1-3 (Migration ages)	Lee et al. (2019) Currently inputted in assessment model and generally match well to the model predictions. Temporal (Seasonal) variation in selex.
Jpn PS	SOJ	Ages 3-5 (Migration ages)	Kanaiwa et al. (2015) Temporal variation in selex.
U.S. Sports	EPO	Ages 1-3 (Migration ages)	Piner (2007) Temporal variation in selex.
Mex PS	EPO	Ages 1-5 (Migration ages)	Aires-da-Silva and Teo (2012) Temporal variation in selex.
Jpn Troll Real-time Monitoring (Winter)	East China Sea	Age 0 (Non-migratory ages)	Tsukahara & Chiba (2019). Survey 12 in the model. Currently inputted in

			assessment model and match well to the model prediction. Representative of two main spawning grounds. Reinforce the survey since 2021.
Jpn Troll Real-time Monitoring (Summer)	East China Sea and the Pacific coast of western Japan	Age 0 (Non-migratory ages)	Currently inputted in assessment model. Survey 11 in the model. Representative of a spawning ground (Nansei island).