INTER-AMERICAN TROPICAL TUNA COMMISSION

1ST EXTERNAL REVIEW OF DATA USED OF STOCK ASSESSMENTS OF TROPICAL TUNA IN THE EASTERN PACIFIC OCEAN

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LONGLINE LENGTH COMPOSITIONS FOR BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN

INTRODUCTION

The exploratory assessment models for bigeye tuna in the EPO include sixteen longline fishery fleets and one longline "survey" fleet. In this document, we describe in detail how the length composition data for those longline fishery and survey fleets are computed. We use the longline length composition data provided by Japan and Korea to compute longline length compositions for this assessment because they are the two most important longline fleets for bigeye in the EPO (Figure 1) and they provide high spatial resolution (1° x 1°) length composition data to the IATTC. Preliminary analysis shows that the two longline fleets (Japan and Korea) have noticeably different selectivities within the same spatiotemporal windows (Figure 2). As such, they are treated as separate fishery fleets and the length compositions for the survey fleet, which includes a Japanese longline index of relative abundance, are based solely on Japanese size data.

In addition to catch-per-unit-effort (CPUE) data, there is a need to standardize the composition data for the survey and fishery fleets (Maunder et al. 2020). The composition data for the survey fleet should represent the condition of the entire population, and that for the fishery fleets should represent the condition of total fish removal. However, only a small portion of CPUE/catch data has the corresponding composition data, indicating that composition data is distributed dramatically more sparsely in space than CPUE/catch data (Figure 3). We therefore need to build a length-specific spatiotemporal model to impute length frequency for unsampled locations and compute CPUE-raised length compositions for the survey fleet and catch-raised length compositions for the fishery fleets.

SURVEY LENGTH COMPOSITIONS

The Japanese longline composition data used to compute the length compositions for the survey fleet are from commercial longline vessels only. The data were measured by fishers before 2011, by both fishers and observers between 2011-2014, and by observers after 2014. The data includes both length and weight compositions and is reported at various spatial resolutions and bin sizes. Survey length compositions should be spatially weighted by CPUE so we need the spatiotemporal fields of both length frequency and fish abundance. The spatiotemporal field of fish abundance can be extracted from the spatiotemporal model that has been developed to provide the index of relative abundance. We need to build another spatiotemporal model, which should be length-specific, to predict the spatiotemporal field of length frequency.

We use VAST (Thorson and Barnett 2017) as the platform to develop the length-specific spatiotemporal for standardizing longline length frequencies due mainly to its ability to account for multiple categories (length bins in this case) simultaneously (Thorson and Haltuch 2018). VAST models encounter probability and positive catch rate separately to account for zero-inflated length frequency observations. Specifically, we specify VAST to use the logit and log link functions for the linear predictors of encounter probability and positive catch rate, respectively, for each length bin. Both linear predictors include an intercept (year-quarter) term, a time-invariant spatial term, and a time-varying spatiotemporal term. Of these three terms, the intercept term is estimated as fixed effects and the other two terms are estimated as random effects. Neither the catchability covariate (HBF) term nor the vessel effects term is included in this model because they are not available in the Japanese longline length composition data. This VAST model treats the four quarters equally (no seasonal component) to be consistent with the "quarters-as-years" approach used in the stock assessment model.

We fit the length-specific spatiotemporal model to the Japanese length composition data. Two steps of pre-processing to the length composition data are applied before model fitting. First, we select only the data collected by commercial vessels with a spatial resolution of 1° x 1°, as data collected by training vessels are not representative of the catches (SAC-07-03d). Second, we remove poorly sampled strata by setting a minimal raw sample size (i.e., the number of fish sampled) of 14 for a 1° x 1° x quarter stratum. The filtered data are available for 1986-2022.

Due to the high dimensions of the length-specific spatiotemporal model, several simplifications are made to make the model computationally more feasible: 1) only 40 spatial knots are used to estimate the spatial and spatiotemporal random effects in the EPO; 2) length bins are regrouped from the original resolution to 10 cm; 3) length frequencies for < 60 cm are negligible and are assumed 0 (length bins in the model: 60-70 cm, 70-80 cm, …, 190+ cm); and 4) all hyperparameters are assumed to be shared among length bins. It should be noted that the predicted length frequencies (lf) for each knot and time do not necessarily sum to 1 across length bins, as the spatiotemporal field of length frequency is predicted for each 10 cm length bin without a multinomial constraint. To solve this problem, we scale the predicted length frequencies to have a sum of 1 for each knot and time.

The length compositions for the survey fleet are CPUE-raised and area-weighted across the EPO. Specifically, the length frequency for the survey fleet ($LF(S)$) in time t and length l is computed as:

$$LF(S)_{t,l} = \frac{\sum_s (a_s \times d_{s,t} \times lf_{s,t,l})}{\sum_l \sum_s (a_s \times d_{s,t} \times lf_{s,t,l})}$$

where a_s is the area of grid s, and $d_{s,t}$ is the fish density in grid s and time t predicted by the spatiotemporal model for CPUE standardization, and $lf_{s,t,l}$ is the length frequency in grid s, time t, and length l predicted by the spatiotemporal model for length-frequency standardization. We use the number of fish sampled/100 as the input sample size of this length composition data and remove poorly sampled quarters by setting a minimal input sample size of 5 for the whole EPO within a quarter.

FISHERY LENGTH COMPOSITIONS

The length compositions for Japanese and Korean longline fisheries are computed separately based on fleet-specific catch and length composition data (Table 1). However, the same method is applied to compute fishery length compositions for the two fleets. The length compositions for a fishery fleet are catch raised within the spatial domain of the fishery. Specifically, the length frequency for a fishery fleet ($LF(F)$) in time t and length l is computed as:

$$LF(F)_{t,l} = \frac{\sum_s (c_{s,t} \times lf_{s,t,l})}{\sum_l \sum_s (c_{s,t} \times lf_{s,t,l})}$$

where c_s is the fleet-specific total catch in grid s and time t, and $lf_{s,t,l}$ is the fleet-specific length frequency in grid s, time t, and length l predicted by the spatiotemporal model for length-frequency standardization. The fleet-specific total catch, reported in the number of fish, is extracted from the IATTC's database and has a spatial resolution of 5° x 5°. To match with this spatial resolution, we aggregate the predicted length frequencies from the length-specific spatiotemporal model from 1° x 1° to 5° x 5°. We use the number of fish sampled/100 as the input sample size of this length composition data and remove poorly sampled quarters by setting a minimal input sample size of 1 for the fishery within a quarter.

The spatiotemporal model for Japanese length-frequency standardization is described in the previous section. The spatiotemporal model for Korean length-frequency standardization has identical specifications except for using a smaller number of spatial knots (30 for the Korean model and 40 for the Japanese model) because Korean data covers a smaller portion of the EPO than Japanese data. The Korean longline length composition data also covers a smaller period with the start year of 2011. Also, we apply the same data processing rules to the Korean and Japanese length composition data.

SUMMARY

Our approaches to computing length compositions for longline fishery and survey fleets are summarized in a flowchart (Figure 7). The longline length compositions for the survey fleet and fisheries fleet have a bin size of 10 cm and are derived from the same predicted length frequency from the length-specific spatiotemporal model. The main difference lies in how the predicted length frequency is raised: to fish density across the EPO for the survey fleet and to catch within a fishery region for the fishery fleets. Another important difference is the source of length composition data, Japan for the survey fleet and both Japan and Korea for fishery fleets. The comparison of all longline length compositions for bigeye tuna in the EPO suggests that the two Korean fishery fleets catch the highest proportion of very large bigeye tuna in the EPO (Figure 5). In the exploratory assessment model for bigeye tuna in the EPO, all purse-seine length compositions are formatted with a bin size of 2 cm from 20 cm to 198+ cm, while all longline length compositions are formatted with a bin size of 10 cm from 60 cm to 190+ cm. To solve this inconsistency in length bins, all longline length compositions are reported in the size composition section of the Stock Synthesis (Methot and Wetzel 2013) data file. Overall, the sample size of the Japanese longline length composition data decreased rapidly since 2011, especially in the inshore tropical region (Figure 6). During that period, the sample sizes of the Korean longline length composition data in the two most important longline fishery regions (2 and 3) are comparable to those of the Japanese longline length composition data.

REFERENCES

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

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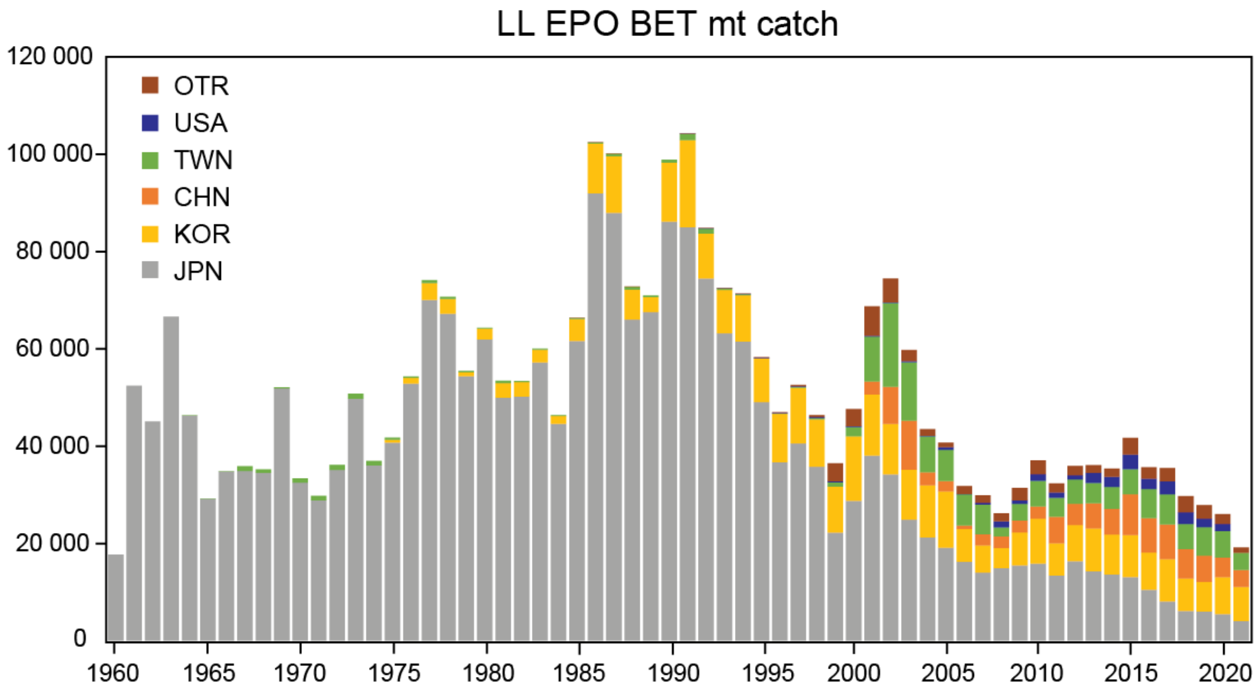

FIGURE 1. Annual longline catch of bigeye tuna in the eastern Pacific Ocean summarized by flag.

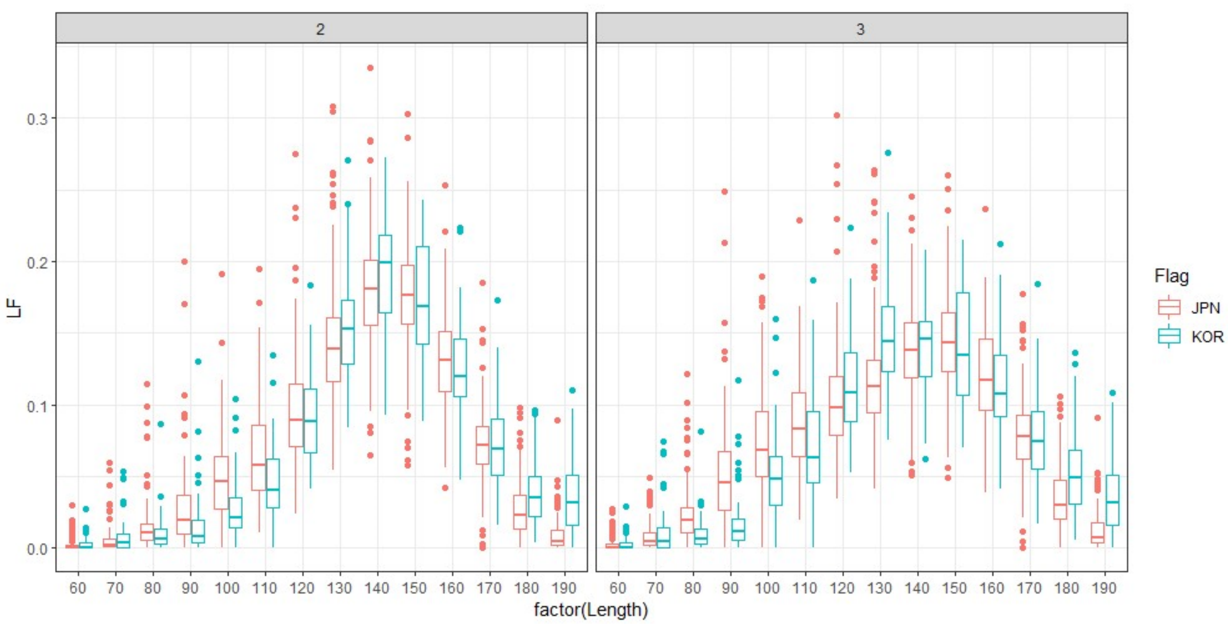

FIGURE 2. Comparison of Japanese and Korean longline length composition data in Areas 2 and 3 between 2011-2020.

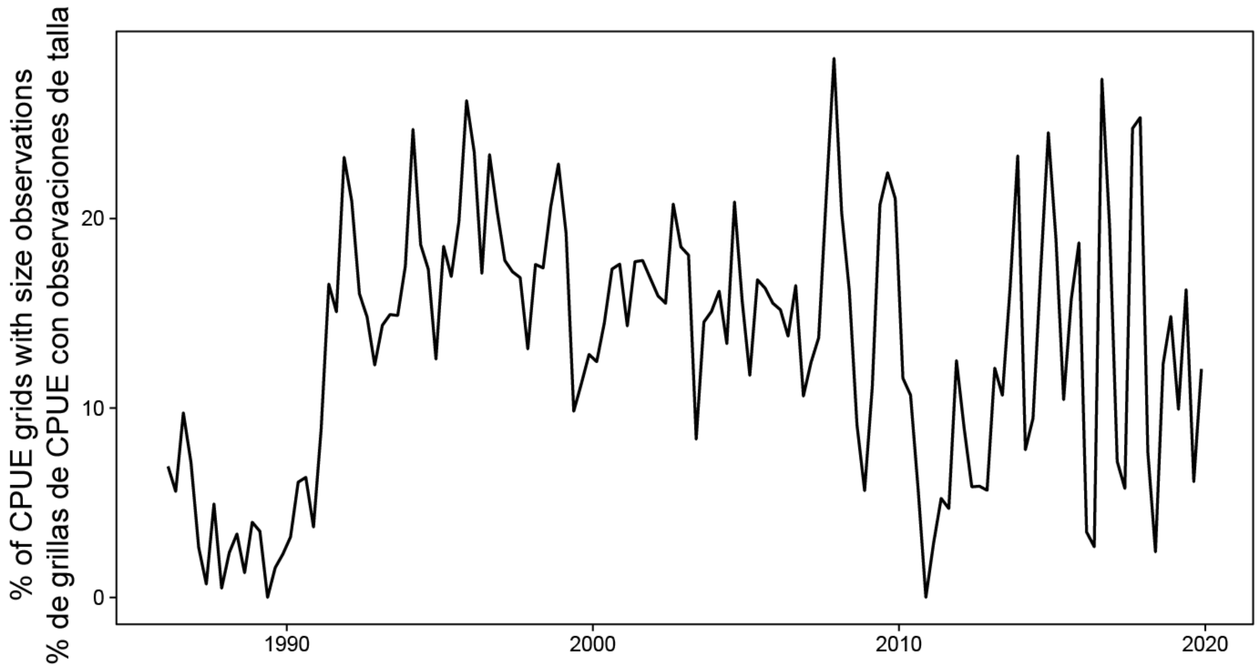

FIGURE 3. The percentage of Japanese longline CPUE grids containing Japanese longline length composition data in the same year-quarter.

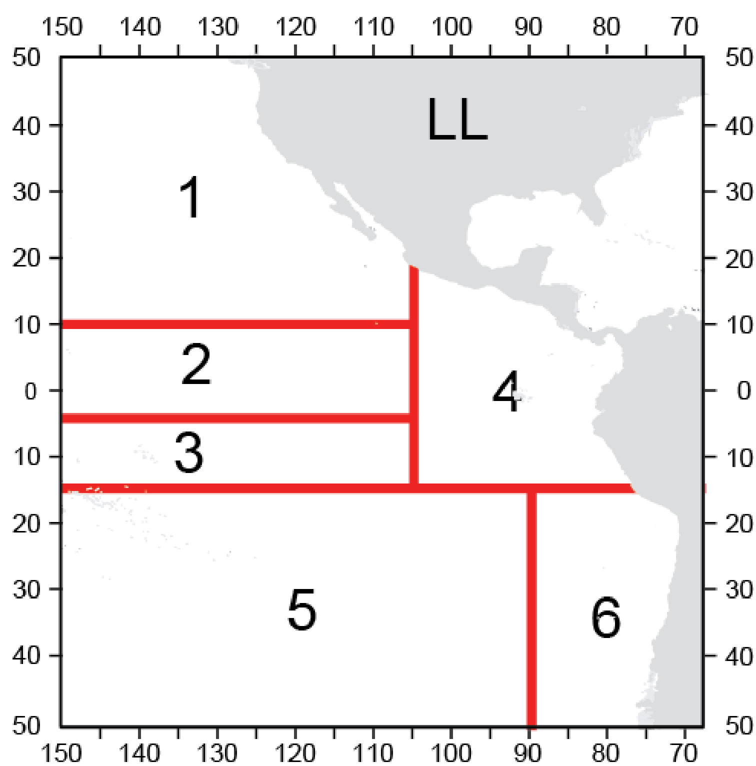

FIGURE 4. The area definition for longline fishery fleets in the exploratory assessment models for bigeye tuna in the eastern Pacific Ocean.

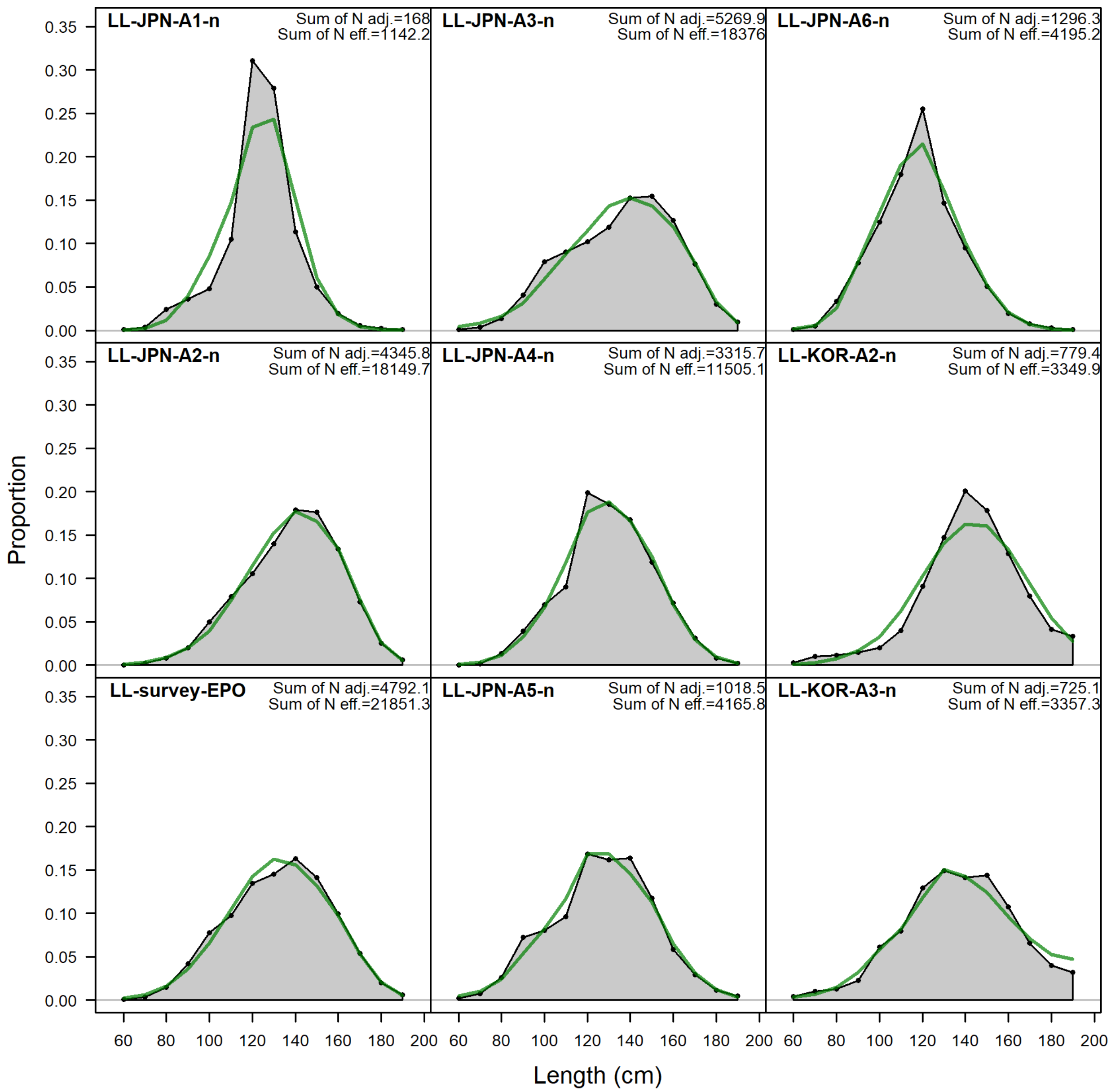

FIGURE 5. Comparison of longline length compositions aggregated across time by fleet (grey polygons). The green lines show model predicted length compositions for each fleet.

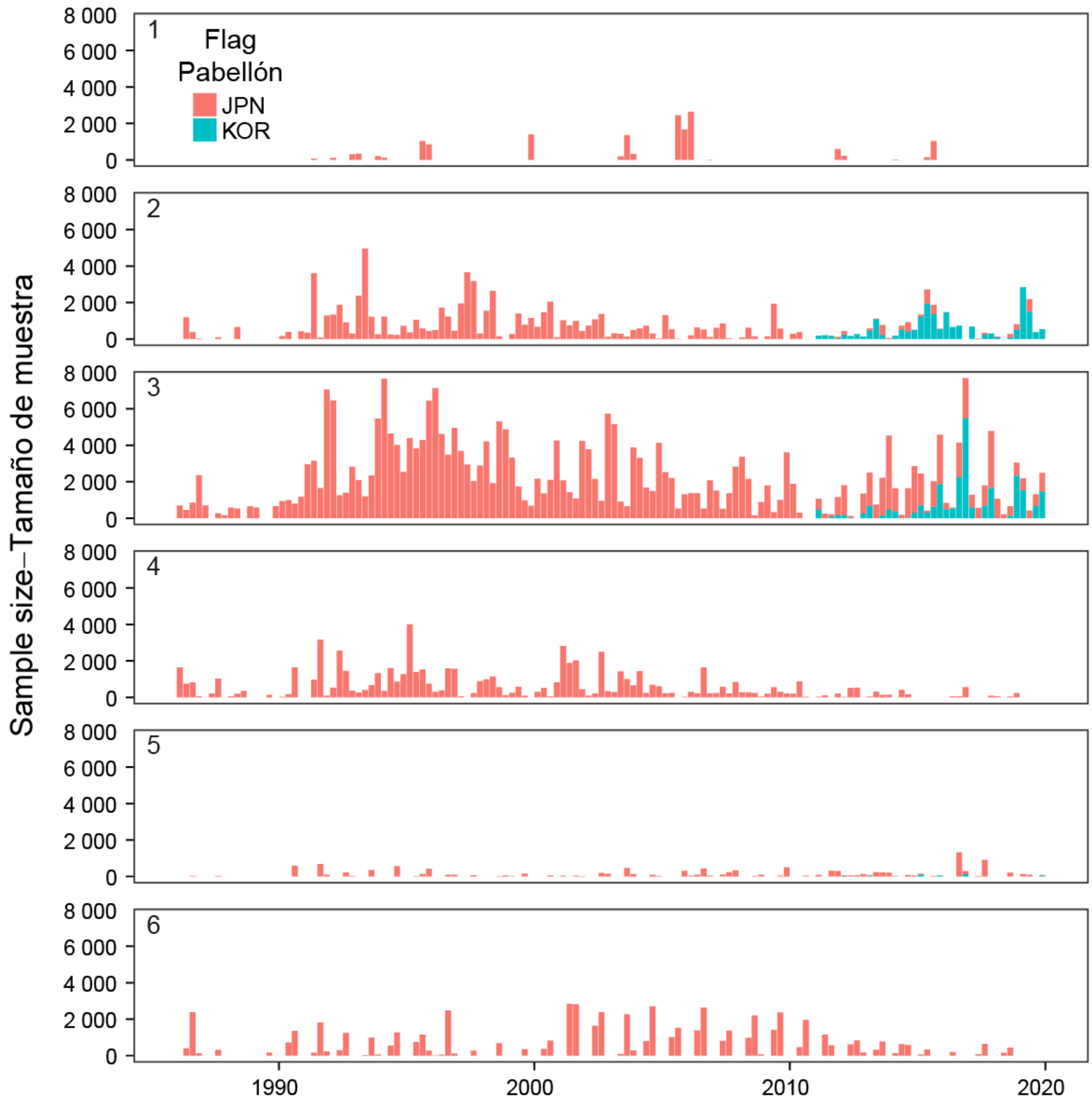

FIGURE 6. Quarterly raw sample size of the longline length composition data for fisheries fleets by region and flag.

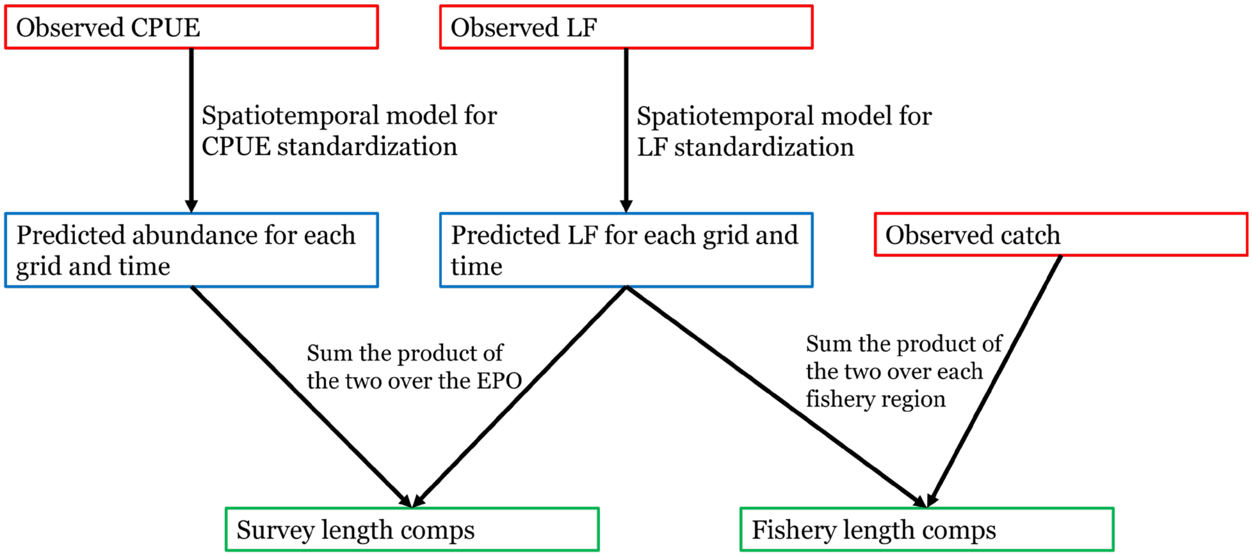

FIGURE 7. Summary of the IATTC's approaches to computing length compositions for longline fishery and survey fleets. Red, blue, and green boxes represent observed data, VAST predictions, and stock assessment inputs, respectively.

TABLE 1. Summary of the longline survey and fishery fleets defined for the exploratory assessment of bigeye tuna in the EPO. The definition of longline fishery areas can be found in Figure 4.

Fleet number	Fleet type	Flag	Area	Catch data	Unit
1	Fishery	Japan	1	Retained catch only	1,000s
2			2		
3			3		
4			4		
5			5		
6			6		
7		Korea	3		
8			4		
9		Japan	1		tons
10			2		
11			3		
12			4		
13			5		
14			6		
15		Korea	3		
16			4		
25	Survey	Japan	2-6	-	1,000s