CPUE and Catch at Size for Pacific Bluefin tuna (*Thunnus Orientalis*) caught by Japanese coastal and offshore longline

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Summary
The standardized CPUE of Japanese longline fishery presented in last PBFWG showed continuously increase trend since 2011 fishing year, while most recent increase at 2019 fishing year was remarkable. The preliminary data in 2020 fishing year indicated continuous drastic increase of nominal CPUE. This was mainly because of the catch in small sized fish which had rarely been caught in the past period before 2018 fishing year. The catch-at-size in recent years also showed the change of size structure in fish caught by Japanese longline fishery, which was dominated by small sized fish. This document describes an additional data filtering for the CPUE standardization to maintain consistency of selectivity of index over time which has been estimated by fitting to the catch-at-size data before 2016 fishing year in the assessment model. This paper also shows the updated catch at size information up until 2020 fishing year in both 3rd and 4th fishing quarter.

Introduction

The time series of CPUE of Japanese coastal longline fishery (JPLL), which was standardized by generalized spatiotemporal GLMM (Thorson, 2015a, b), had been used as an abundance index for large sized Pacific Bluefin Tuna (PBF) mostly corresponding to the size of spawning stock biomass (SSB) in the PBF assessment (Tsukahara et al 2020, ISC 2020). The updated index which was presented in last PBFWG showed a continuous increase trend since 2011 fishing year (FY: July to June in following year) up until 2019 FY. On the other hand, this fishery has been subject to strict fishery management after 2017 FY, and hence, every year, there were the suspension periods of landing PBF in the main fishing season. To date, the operation data during suspension period was excluded from the dataset for the standardization, while the suspension period gradually became earlier and longer possibly due to the recent high CPUE. In 2020 FY, longline fishermen have introduced the individual quota (IQ) system to allow them to have balanced opportunity to catch PBFs. The quota for each vessel differed and could change during main fishing season due to the additional allocation for this fishery and some transfers of quota. However, the logbook that was used as input data for standardization have not recorded the quota information, i.e., quota itself and degree of consumption, but just recorded operation and catch information. In order to determine the suspension period by each vessel in 2020 FY, it is necessary to merge the operational data from logbook and IQ data.

In order to estimate the selectivity for the removal by JPLL fishery and for the vulnerable biomass by this abundance index, length measurement in some major landing ports was conducted since 1993 FY. The measurement data in each prefecture was raised according to the coverage of size measurement to the total weight of landing and aggregated as two separate catch-at-size from January to March and from April to June, respectively. In recent year, small sized fish, which was less than 150cm and hardly observed until 2015 fishing year, was dominant in the size composition in both fishing seasons. However, the index has been estimated from the longline operational data at the fishing ground where the small sized fish had rarely been caught over time. To prioritize the consistency of index selectivity, PBFWG at 2020 assessment decided not to use the size composition

data after 2017 FY for estimation of selectivity on this fishery. PBFWG also recommended that more work will be needed to understand the potential effects of recent management measures on the stability of the model process linking to this and other data (ISC 2020).
Unfortunately, the compilation of logbook data merging with IQ information is behind schedule largely due to the COVID-19 pandemic, and hence the information on CPUE for 2020 FY is very limited and preliminary at this stage. This document presents a suggestion for additional data filtering in standardization process based on the preliminary data and the update results of catch at size in 3rd and 4th fishing quarter (Fqt) up until 2020 FY.

Materials and Methods

Data collection and filtering for CPUE standardization

The fishery operational data by JPLL has been collected by Japan Fishery Agency and compiled by Japan Fisheries Research and Education Agency since 1994. The logbook data for last couple of years is going to be updated partially due to the delay of submission and electronification. The logbook data contains individual records of fishing operation: date (year, month and day) and location (latitude and longitude) of longline set, total number of hooks per set, number of hooks per basket (HPB), catch in number and cumulative catch in weight by various fish species including PBF. Some data in the logbook could be regarded as irrelevant operations and misreporting for PBF. To remove such data, data filtering was conducted by following criteria: (1) vessel size more than 20 gross register tonnages (GRT), (2) season other than April to June, (3) the catch in number more than 50 per a cruise, (4) number of hooks less than 1,000, (5) HPB less than 9 and more than 24, (6) the locations where PBF was not caught over 5 years through the data period from 1994 to 2020 (Fig. 1), (7) locations in the south of 23-degree north latitude, north of 35-degree of north latitude and east of 145-degree east longitude (Fig. 1), and (8) suspension and buffer period for the time of fishery association arranging the quota.
In terms of the longline fishery management in Japan, the fishery specific catch quota for the large PBF (30 kg and larger) has been implemented since 2018 calendar year (WCPFC-NC 2019) to comply the conservation and management measure (WCPFC CMM 2018-02) adopted in the Western and Central Pacific Fisheries Commission (WCPFC). The catch quota was allocated from the national government to the longline fishery association and the association has managed the quota under the supports of the government. After 2017 FY, the fishermen were required to suspend their landings of PBF when the catch amount almost reached the fishery association’s quota. Based on the suspension periods, the data during the following date was removed from this analysis;

2017 FY: from 21st May to 30th June,
2018 FY: from 11th May to 19th June,
2019 FY: from 21st April to 30th April, from 11th May to 31st May, from 11th June to 30th June and first three days in each month.

In 2020 FY, fishery association have introduced the IQ system to allow each fisherman to have balanced opportunity to catch PBFs. The quota for each vessel differed and could change during the main fishing season due to the additional quota and some transfer between vessels which were owned by same company. In order to determine the suspension period by vessels (i.e., not targeting PBF due to the exhaustion of quota), consumption information of each vessel was collected in addition to the logbook in this year. However, the compilation of logbook data merging with IQ information is behind schedule due to the COVID-19 and it seems to be insufficient to calculate the standardized CPUE. Because the information on CPUE is very limited at this stage, this paper present preliminary value of nominal CPUE up until 2020 FY. Further research on the practical information on quota management is needed for this area.

Spatiotemporal model

The filtered set-by-set logbook data including catch in number and fishing effort, number of hooks, were aggregated by spatial stratum (i.e., 1 x 1 degrees) and temporal strata (i.e., year and season) to improve the estimation efficacy of spatiotemporal model. The seasonal stratum, Day 10, was defined as intervals of every 10 days from April 1 to June 30 except for the end of May, only which have 11 days. The spatiotemporal modelling package, the Vector Autoregressive Spatio-Temporal (VAST) package, is currently available as an R-package (Thorson, 2019). However, the VAST was not directly used in this study. Instead of using the VAST, the original C++ codes of VAST were modified to conduct flexible modeling and R-package “TMB” (version 1.7.15) was used for the optimization of the model mainly to incorporate seasonal effects (Day 10) into spatiotemporal model. For PBF spatiotemporal model, one step model only by catchability was used to predict an abundance index as in the case of blue shark standardization (Kai et al, 2017). Since the catch number of PBF is count data which has overdispersion even after data filtering and aggregation by spatial and temporal strata, the negative binomial model (NB) was used as the observation models. Catch in number was used as a response variable. The models selected in last update based on the AIC have main effects of Year, t, Day10, d, Site, s, and three-dimensional interaction term between Year and Site day10, with offset terms by Hooks, h.

$$p(i) = \beta(t_i) + \xi(d_i) + \delta(s_i) + \upsilon(t_i, s_i, d_i) + h_i \qquad \text{(Eq. 1)}$$

where β, ξ,δ,υ is the inference of main effects of Year, Day10, Site and interaction of Year and Site. Only year effect, β, was treated as fixed effects and the other effects including interactions were treated as random effects which have correlation structure, either Gaussian Markov Random Field for site effects or one-dimension auto-regression for Year, Day10 effects.

Data collection and treatment for catch-at-size

The catch-at-length of PBF caught by Japanese coastal longliners was estimated using size-measurement and sales slip data for longline which were obtained at 10 main landing ports in five prefectures (Fig. 2), mainly collected by the “Research Project on Japanese bluefin tuna (RJB)”. Some size-measurement data from other research projects such as observer data were also used. The data from January to March (3rd Fqt) and from April to June (4th Fqt) during 1993 to 2020 FY (1st and 2nd quarters of 1994 to 2021 calendar years) was used for the estimation in each quarter. Note that the data in the latest year should not be considered complete due to delay of data collection, thus the result of catch-at-length in 2020 FY is preliminary.

The catch-at-length was estimated using the same method as proposed by Hiraoka et al. (2015). The length frequency (fork length) was estimated by "number" of actual measured fish with relative "weight" for measured fish and total catch. When fish weight was not measured for the size measurement, the weight of measured fish was calculated from measured length using existing weight-length relationship (Kai 2007). The estimating method can be described by the following equations:

$$Coverage_{yqk} = w_{yqk} \,/\, c_{yqk} \quad \text{(Eq. 2)}$$

$$N_{iyq} = \sum_{k=1}^{K} \left(n_{iyqk} \,/\, Coverage_{yqk} \right) \quad \text{(Eq. 3)}$$

where N_{iyq} is the number of fish at the length bin of i occurred in the population at the quarter q of calendar year y. K is the total number of prefecture stratification. n_{iyqk} is the number of measured fish at the length bin of i in prefecture stratum k at quarter stratum q for year y. w_{yqk} is the total weight of them. c_{yqk} is the total catch weight in prefecture stratum k at quarter stratum q for year y. As the quarter stratum, a single quarter, either 1st or 2nd quarter of calendar year, was used for each catch-at-length. The prefecture stratum was following 5 prefectures: Miyagi, Chiba, Wakayama, Miyazaki, and Okinawa, where the size data was obtained (Fig. 2).

The coverage, which is the rate of the total weight of measured fish to the total weight of catch based on the sales slips for each prefecture, quarter and year, is used for the estimation of the catch-at-length. The number of measured fish divided by the coverage are raised to the estimated number of caught PBF (Eq. 1). However, the coverage of only Okinawa prefecture since 2007 has been over than 100% due to the deals outside of landing port. The fisheries cooperative sometimes deals with the PBF in other than their own port to sell it at higher price. When it often happens, there are measurement data at landing port, although there are not sales slip at landing port. It causes the number of caught PBF underestimated less than the number of measured PBF. Therefore, the present paper makes one change, that the coverage which is over than 100% was changed to 100 (actually "1.0" in the equation), and the number of caught PBF was estimated as same with the number of measured fish.

Results and discussion

CPUE

The numbers of used hooks, i.e., effort for this CPUE, caught PBFs and nominal CPUE are shown in Table 1. The recorded number of hooks in 2020 FY was fairly lower than those in recent years and approximately 40% lower than that in 2019 FY. This is largely because of the COVID-19 pandemic and it is expected that the logbook data merging with IQ information, which record additional more than 100 trips, will be updated within this year. Therefore, it is thought that the

CPUE standardization at this stage is premature unfortunately.
On the other hand, the nominal CPUE in 2020 FY showed quite steep increases (Table 1) after 2019 FY, mainly because of the catch in small-sized fish. There is a data filtering to prevent a contamination of much small-sized fish from being in standardization data by removing operation in the east water of 145-degree east longitude (Fig. 1). However, since 2019 FY, the area where averaged weight in catch was relatively small, around 50 kg, was observed inside of the analysis area (Fig. 3). The estimated selectivity for this index in last assessment indicates that 5% selection rate by this gear is around 151 cm, which is corresponding to 71 kg based on the length weight relationship used in assessment model (Fig. 4). The weight recorded in logbook is product weight, and hence less than approximately 60 kg should rarely have been caught in this fishery according to the selectivity. However, the number of fish whose averaged weight in one operation is less than 60kg was observed frequently in 2019 FY (and perhaps 2020 FY too) and was the cause of recent drastic increase of CPUE (Fig. 5).
Based on these observations, authors would like to suggest an additional data filtering for the abundance index used in 2022 next assessment, which is to remove the number of caught fish if average weight of those fish in an operation is less than 60 kg in logbook. This filtering enables size range of vulnerable biomass in the standardized CPUE to be stable and to be consistent with its selectivity. After removing fish less than 60kg, the nominal CPUE still showed moderate increase trend (Table 1).

Catch-at-Size

Estimated catch-at-length data from April to June, which is 4th Fqt in the assessment model, showed that the main part of the Japanese coastal longline catch has been constituted by some strong cohorts (Fig. 6: blue lines). For example, before the previous strong cohorts consisted of 1990 and 1994 year-classes became small and mostly disappeared in 2012 FY, 2007 and/or 2008 year-class increased and started to consist of a new strong cohort in 2010 FY. These results correspond to the size and age compositions of PBF caught by Taiwanese longline (Shiao 2017), which reported that 2005-2009 year-cohorts increased in 2013-2015 after strong 1994 and 1996 year-cohorts decreased. In addition to the cohort of 2007 and/or 2008 year-class, 2010 and/or 2011 year-class started to be seen in 2014 FY and now composes the strongest cohort.
In recent year, small sized fish, which was less than 150cm and hardly observed until 2015 FY, was dominant in the size composition in 4th Fqt. This change in size composition was continuously observed and became noticeable after 2017 FY. Those individuals were mainly caught in east water of 145-degree of east longitude, where the data excluded from CPUE standardization, and thus it was determined that the catch-at-length after 2017 FY should not be included in the likelihood component to prioritize the stability and consistency of selectivity for this index in the 2020 assessment. However, this treatment now leads to misspecification for the removal of this fleet because of the substantial increase of small sized fish in caught PBF. This trade-off should be discussed in PBFWG.

Conclusion

In 2020 FY, fishery association have introduced the IQ system to allow each fisherman to have balanced opportunity to catch PBFs. The compilation of logbook data merging with IQ information is behind schedule due to the COVID-19 pandemic and it seems to be premature to calculate the standardized CPUE. The nominal CPUE in 2020 FY showed quite steep increases (Table 1) after 2019 FY, mainly because of the catch in small-sized fish. Therefore, authors would like to suggest an additional data filtering for the abundance index used in 2022 next assessment, which is excluding the number of catch record if average weight of those fish in one operation is less than 60 kg in logbook.

Regarding catch at length data, small sized fish, which was less than 150cm and hardly observed until 2015 fishing year, was dominant in the size composition in 4th Fqt. Those individuals were mainly caught in eastward area of main operation ground where the data excluded from CPUE standardization, and thus it was determined that the catch-at-length after 2017 should not include the likelihood component to prioritize the stability and consistency of selectivity for this index. However, this treatment leads to misspecification for the removal of this fleet because of the substantial increase of small sized fish in caught PBF. This trade-off should be discussed in PBFWG.

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Table 1 Annual catch in number, the number of longline operations and nominal CPUE in logbook data from April to June, which have been complied to date. This table include the data in suspension period.

		data in Logbook for standardization			After removing <60kg PBF	
Calendar Year	Fishing Year	Catch in Number	Effort (x1000 hooks)	Nominal CPUE	Catch in Number	Nominal CPUE
1994	1993	2707	5155	0.525	2687	0.521
1995	1994	1595	4755	0.335	1574	0.331
1996	1995	2501	5220	0.479	2471	0.473
1997	1996	2629	5686	0.462	2589	0.455
1998	1997	3109	6684	0.465	3097	0.463
1999	1998	3830	9665	0.396	3823	0.396
2000	1999	2304	8787	0.262	2299	0.262
2001	2000	1813	9584	0.189	1813	0.189
2002	2001	2109	9762	0.216	2094	0.214
2003	2002	2622	8805	0.298	2618	0.297
2004	2003	3644	10196	0.357	3634	0.356
2005	2004	3830	9747	0.393	3783	0.388
2006	2005	1992	9434	0.211	1981	0.210
2007	2006	2976	9011	0.330	2953	0.328
2008	2007	1471	9292	0.158	1454	0.156
2009	2008	1280	10936	0.117	1251	0.114
2010	2009	709	9025	0.079	686	0.076
2011	2010	496	8873	0.056	442	0.050
2012	2011	369	9455	0.039	360	0.038
2013	2012	738	9507	0.078	735	0.077
2014	2013	681	8543	0.080	670	0.078
2015	2014	511	6773	0.075	507	0.075
2016	2015	631	5710	0.111	607	0.106
2017	2016	1190	8014	0.148	1160	0.145
2018	2017	506	4999	0.101	479	0.096
2019	2018	1287	7531	0.171	1263	0.168
2020	2019	1934	6215	0.311	1135	0.183
2021	2020	2715	3940	0.689	613	0.156

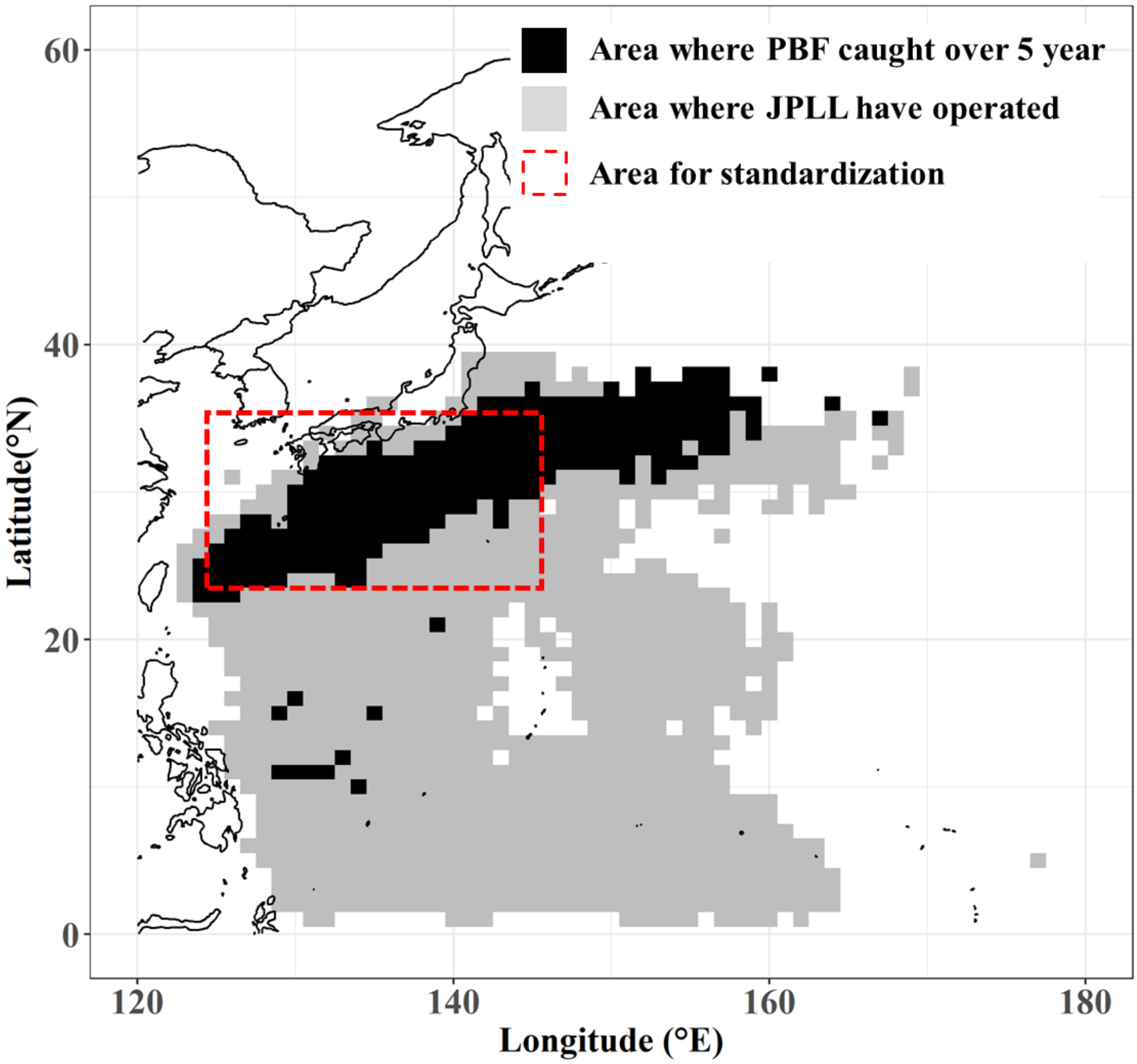

Figure 1. The spatial distribution of operation by Japanese coastal longline from 1994 to 2019.

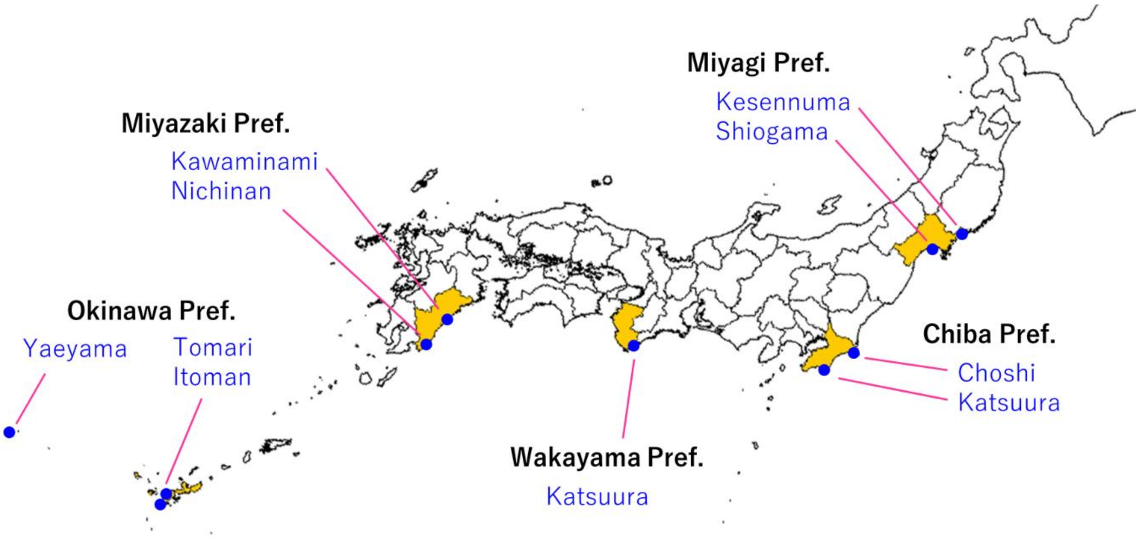

Figure 2. Location of prefectures (yellow area) and fishing ports (blue circle) where the PBF caught by Japanese coastal longliners was measured for size data.

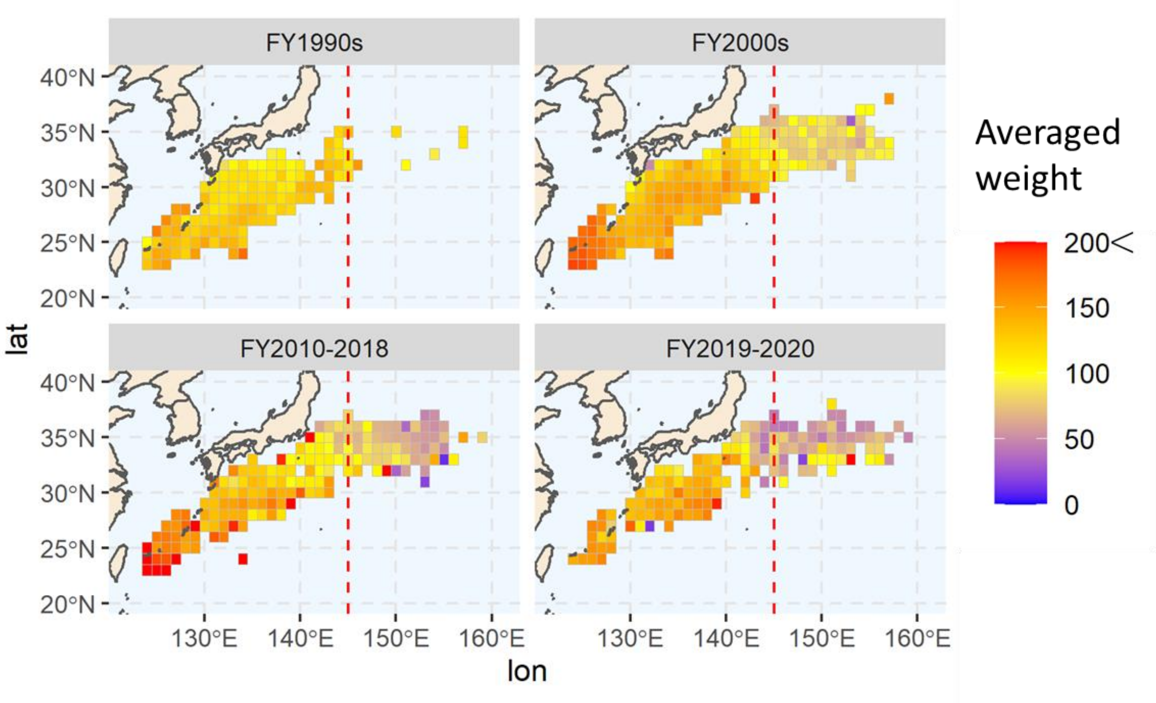

Figure 3. Spatial distribution of averaged weight in caught PBF by decades in comparison to that in update period. Red dashed line is the 145-degree of east longitude.

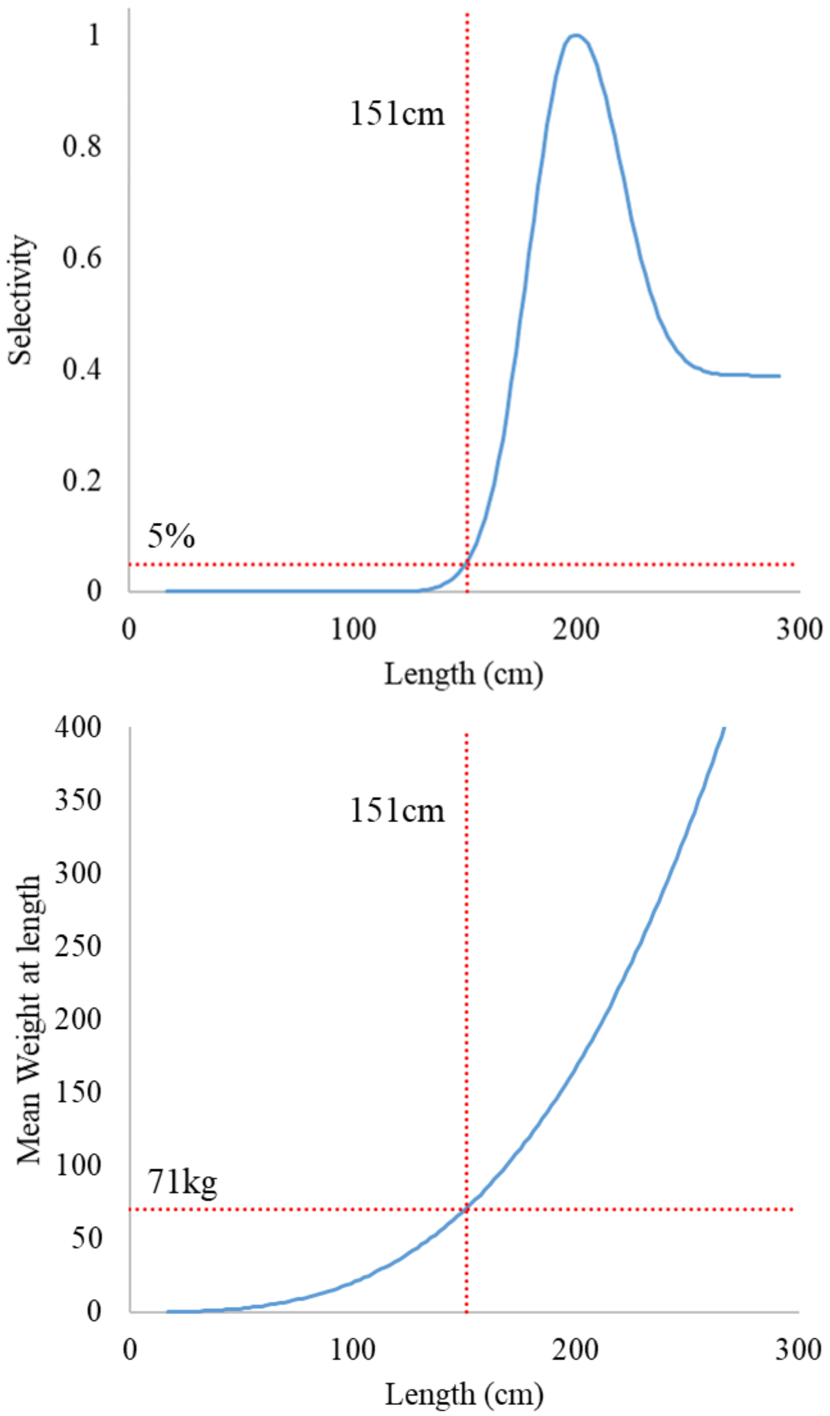

Figure 4. Selectivity for JPLL standardized CPUE (top) and length-weight relationship (bottom) estimated and used in last assessment.

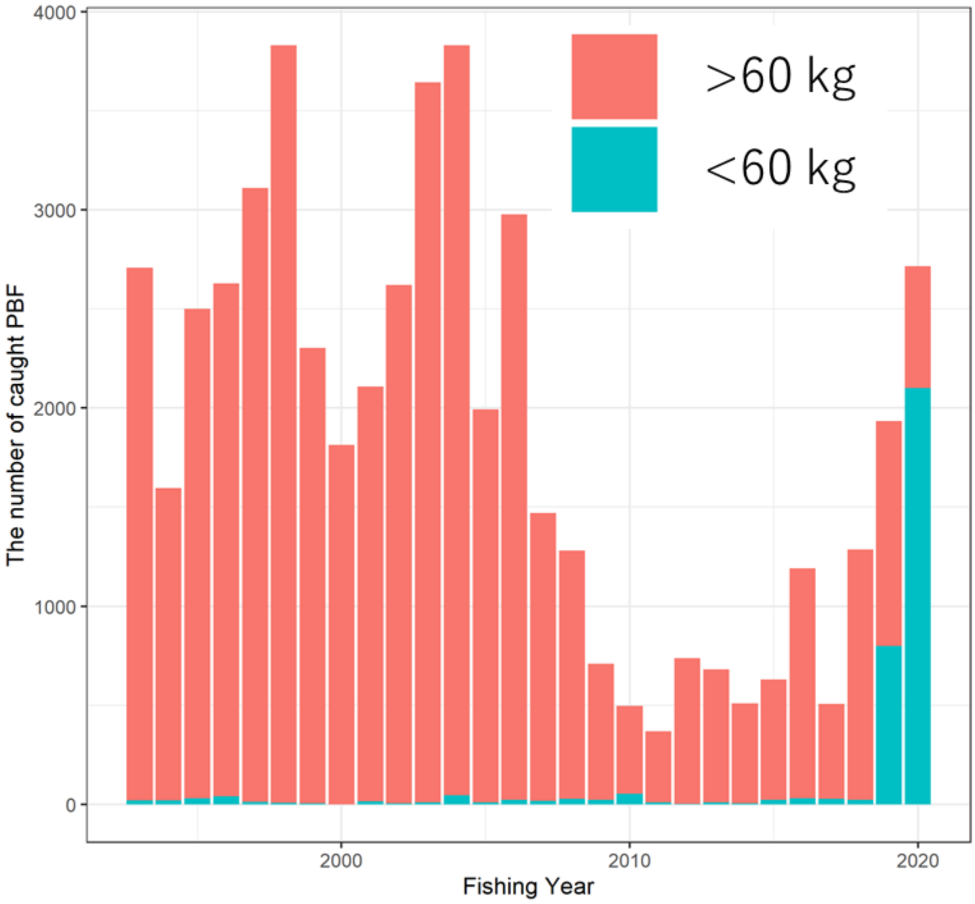

Figure 5. The number of catch in number by the averaged weight, less than 60 kg (blue) and over than 60 kg (red).

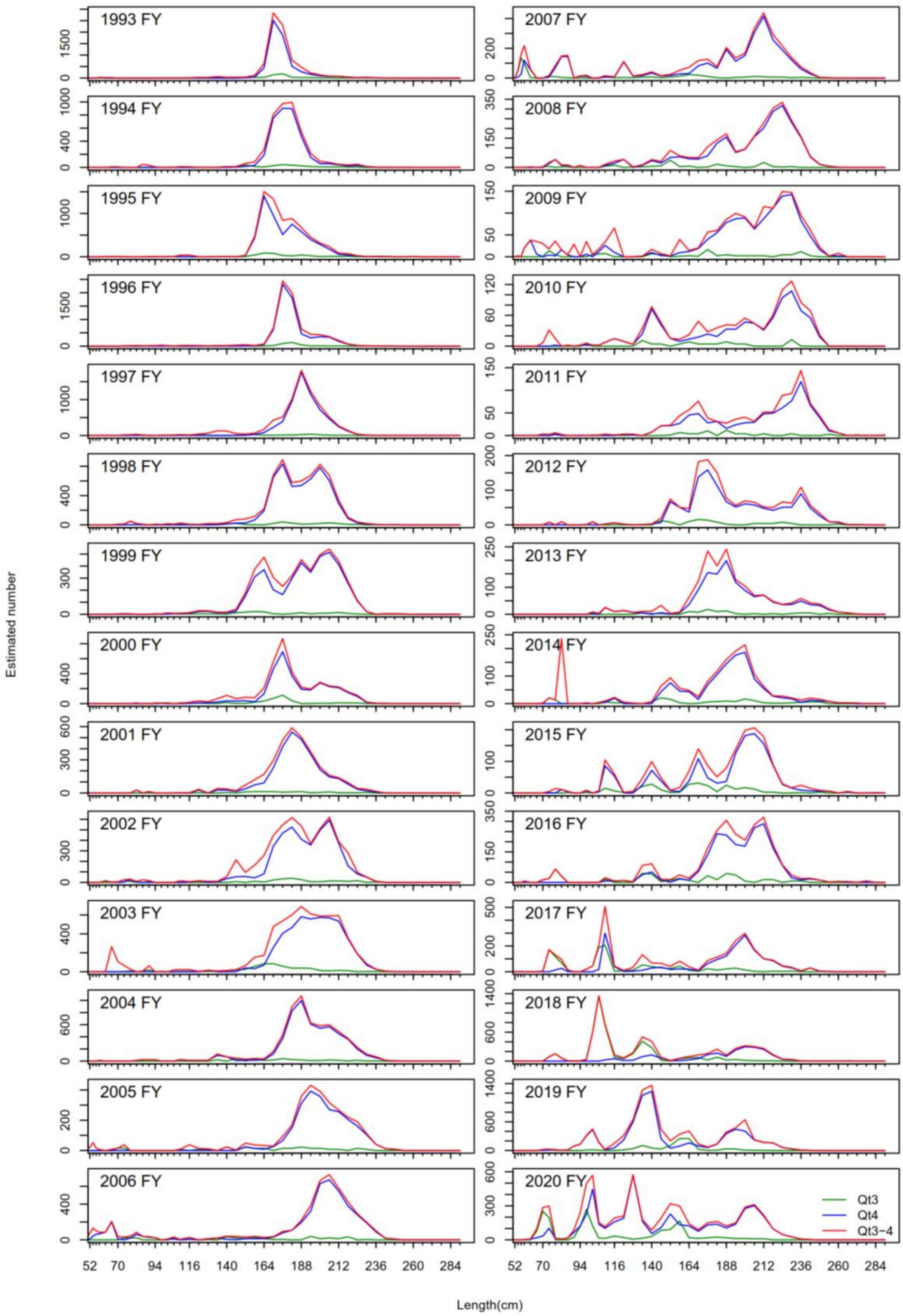

Figure 6. Estimated catch-at-length of PBF caught by Japanese coastal longliners in 3rd (green line), 4th (blue line), and 3rd to 4th (red line) quarters of fishing year, respectively. Vertical axis indicates estimated number of caught PBF. Horizontal axis indicates fork length of PBF (cm). The catch-at-length of 2020 FY is preliminary.