Updating of standardization of bigeye tuna CPUE by Japanese longline fishery in the Indian Ocean

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Summary

Standardization of bigeye tuna CPUE up to 2021 by Japanese longline fishery in the Indian Ocean was conducted using the Generalized Linear Model (GLM) with lognormal error structure. Cluster analysis was conducted before standardization, and cluster number was used for main effect as well as year, quarter, vessel ID and five degree latitude/longitude block. Area definition is the same as that for 2019 IOTC bigeye tuna stock assessment. CPUEs show decreasing trend from early 1980s to late 2000s, and then CPUEs show increasing trend. The trend of CPUE was usually similar to that in the previous study.

1. INTRODUCTION

Bigeye tuna is one of main target species for Japanese longline fishery in the Indian Ocean. Its abundance indices are very important for stock assessment of this species because they have high spatial and temporal coverage, and detailed information on catch and effort is available through logbooks.

Satoh and Okamoto (2012), Matsumoto et al. (2013; 2015; 2016), Ochi et al. (2014) and Matsumoto (2017; 2018; 2019) reported area aggregated annual standardized Japanese longline CPUE for bigeye tuna based on GLM (generalized linear model, log normal error structured) for an indicator of the stock. Also, area specific CPUE for integrated models was reported at the IOTC WPTT meetings (Ochi et al. 2014, Matsumoto et al. 2015; 2016, Matsumoto, 2017; 2018; 2019). These are based on so called ‘traditional method’.

In 2016, IOTC joint CPUE analysis (CPUE workshop) started and ‘joint CPUEs’ were created for bigeye and yellowfin tuna, based on Japanese, Taiwanese and Korean longline operational data (Hoyle et al., 2016). These models account for fishing power based on vessel ID where available, and use cluster analysis to incorporate targeting. Joint CPUEs were considered to be more representative of status of the stocks and so were used for base models of stock assessment. At that time fleet-specific CPUE indices were prepared for Japanese longline using the same methods, but were not presented, so it was not possible to compare the joint and Japanese-only longline CPUE indices. In 2017 the joint CPUE analysis workshop was held and CPUE indices for each fleet as well as joint CPUE were created (Hoyle et al., 2017). Japanese longline CPUE for bigeye and yellowfin tuna created at that workshop was reported by Matsumoto et al. (2017). They reported that the trend of both CPUEs was mostly similar to those by traditional method, but there are some differences especially in the early period. Also in 2018 and 2019, joint CPUE analysis workshop was again held and CPUE indices for each fleet as well as joint CPUE by Japanese, Korean, Taiwanese and Seychelles longline fishery combined were created (e.g. Matsumoto et al., 2018, Hoyle et al., 2019, Matsumoto and Hoyle, 2019). Those CPUE incorporated cluster analysis and vessel effect.

A new collaborative study for developing the abundance index of tunas started in late 2019 by Japanese, Korean and Taiwanese scientists has been conducted and the results of CPUE standardization for Indian Ocean yellowfin tuna (Kitakado et al., 2021a,b, Matsumoto et al., 2021), albacore (Kitakado et al., 2022, Matsumoto, 2022a) and bigeye tuna (Matsumoto, 2022b) were reported (joint CPUE and each fleet CPUE). In this collaborative study, the methods are similar to those mentioned above, but some changes have been made such as different cluster analysis. In this study, updated CPUE up to 2021 of Indian Ocean bigeye tuna caught by Japanese longline fishery is reported.

2.MATERIALS AND METHODS

The methods to standardize CPUE are basically the same as conventional regression analyses in the CPUE collaborative study mentioned above (e.g., Matsumoto, 2022b).

Catch and effort data

Operational level (set by set) Japanese longline logbook data with vessel ID were used. The data were available for 1975-2021 (data for 2021 are preliminary). The data include the fields year, month and day of operation, location to 1° of latitude and longitude, vessel identifier (call sign and vessel registration number), number of hooks between floats (HBF), number of hooks per set, and catch in number of each species. In the previous collaborative studies, vessel ID was available from 1979, but currently the information for longer period (from 1975) is available. Each set was allocated to subregion (subarea) (Fig. **1**), which is the same as that in the previous (2019) IOTC stock assessment of bigeye tuna. Fig. 2 shows species composition of catch in number in each area, and Fig. 3 shows the numbers and proportion of zero and positive catch in the catch and effort data used for CPUE standardization.

Cluster analysis

The data were clustered using the approach described by Kitakado et al. (2021a, b, 2022), which used Ward's minimum variance and the complete linkage methods. Species composition in number of the catch was aggregated for 10-days period (1st-10th, 11th-20th, and 21st- for each month), and was used for cluster analysis. In the previous analyses (e.g. Hoyle et al., 2017), the data was aggregated for 1 month period, but shorter period was used in this study for better reflecting targeting. Catch for southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), sharks (SKX) and other fish (OTH) were used for species composition. Data were also clustered using the kmeans method, which minimises the sum of squares from points to the cluster centres.

GLM (Generalized Linear Model):

After cluster analysis, cluster numbers were assigned to catch and effort data aggregated by year, month, vessel ID and 1 degree latitude/longitude blocks. This data set was used for CPUE standardization.

GLM (generalized linear models) with lognormal analyses was conducted considering low zero catch ratio (Fig. 3). The following initial (full) models were used:

Lognormal

$$Log(CPUE + k) \sim \ year + q + vessel + latlon5 + cluster + \ year * q + \epsilon$$

where $year$: effect of year, q: effect of quarter; $vessel$: effect of vessel ID; $latlon5$: effect of five degree latitude and longitude; cluster: effect of cluster; $year*q$: interaction between year and quarter; ϵ: error term; k: constant (10% of overall mean nominal CPUE)

All the covariates were incorporated as fixed effect. Main effects and interactions were selected at 1% significance level. As for diagnostics of CPUE standardization, residual distributions, Q-Q plots and influence plots were produced.

3. RESULT AND DISCUSSION

Species compositions were plotted by cluster for each region (**Fig. 4**) and each region and year (**Fig. 5**). Dominant species differed depending on clusters, but there was at least one cluster in each region in which bigeye tuna was dominant. Number of clusters were 4 or 5 for each region.

The results for ANOVA (type 2) are shown in Table **1**. All the effects and interactions were significant at 1% level. Fig. 6 shows comparison of bigeye tuna CPUE by area, and Fig. 7 shows comparison of CPUE in each area with nominal CPUE and standardized CPUE in the previous study (Matsumoto and Hoyle, 2019), which also incorporated cluster analysis and vessel effect. The trend of CPUE is usually similar among areas. CPUEs show decreasing trend from early 1980s to late 2000s, and then CPUEs show increasing trend although CPUE in R1N is not available in recent years due to lack of operations. The trend of CPUE in this study is usually similar to those in the previous study.

Fig. 8 shows distribution of standardized residuals and QQ plots. It seems that the distributions are not largely skewed. **Fig. 9** shows influence plots. In some cases there is historical change of the effect. Difference of historical change of the effect by area is also observed. For example, vessel effect is decreasing in R2, although there is no clear trend in R3.

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Table 1. Analysis of variance (type 2) for the GLM analyses.

R1N

	LR Chisq	Df	Pr(>Chisq)	
Year	2637.6	38	< 2.2e-16	***
Q	612.0	3	< 2.2e-16	***
LatLon	546.7	14	< 2.2e-16	***
Cluster	26121.2	4	< 2.2e-16	***
Vessel	6783.0	609	< 2.2e-16	***
Year:Q	2508.5	104	< 2.2e-16	***

R1S

	LR Chisq	Df	Pr(>Chisq)	
Year	2427.9	46	< 2.2e-16	***
Q	445.3	3	< 2.2e-16	***
LatLon	2463.6	27	< 2.2e-16	***
Cluster	18317.3	3	< 2.2e-16	***
Vessel	8016.7	678	< 2.2e-16	***
Year:Q	2501.5	130	< 2.2e-16	***

R2

	LR Chisq	Df	Pr(>Chisq)	
Year	2763.1	46	< 2.2e-16	***
Q	43.5	3	1.958e-09	***
LatLon	1934.3	32	< 2.2e-16	***
Cluster	24971.3	4	< 2.2e-16	***
Vessel	9750.2	795	< 2.2e-16	***
Year:Q	2244.0	136	< 2.2e-16	***

R3

	LR Chisq	Df	Pr(>Chisq)	
Year	2940.3	46	< 2.2e-16	***
Q	2864.1	3	< 2.2e-16	***
LatLon	4672.4	73	< 2.2e-16	***
Cluster	25669.2	3	< 2.2e-16	***
Vessel	20170.6	973	< 2.2e-16	***
Year:Q	2987.2	138	< 2.2e-16	***

Significance level: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

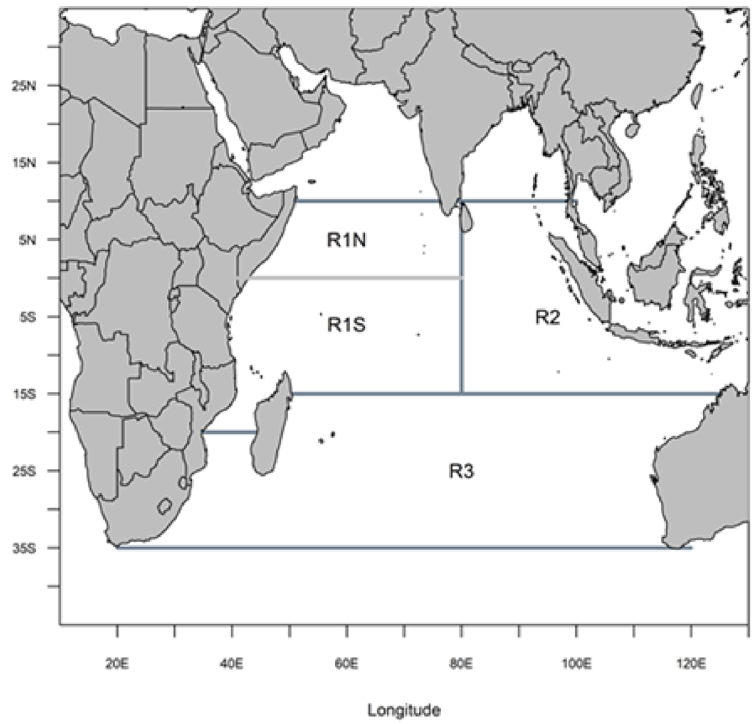


Fig. 1. Area used for the GLM analysis.

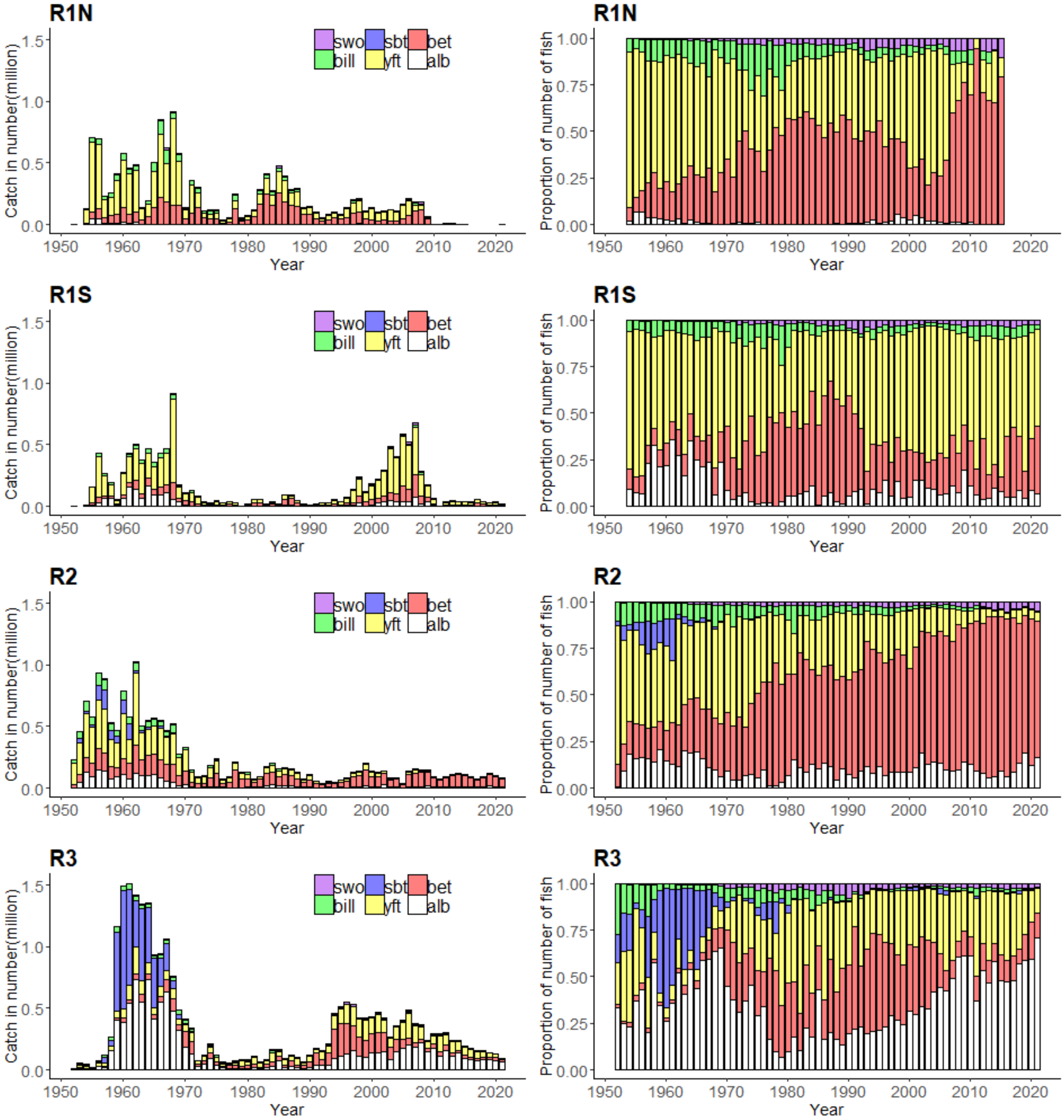


Fig. 2. Species composition of catch in number in the Indian Ocean by the Japanese longline fishery in each area shown in Fig. **1**.

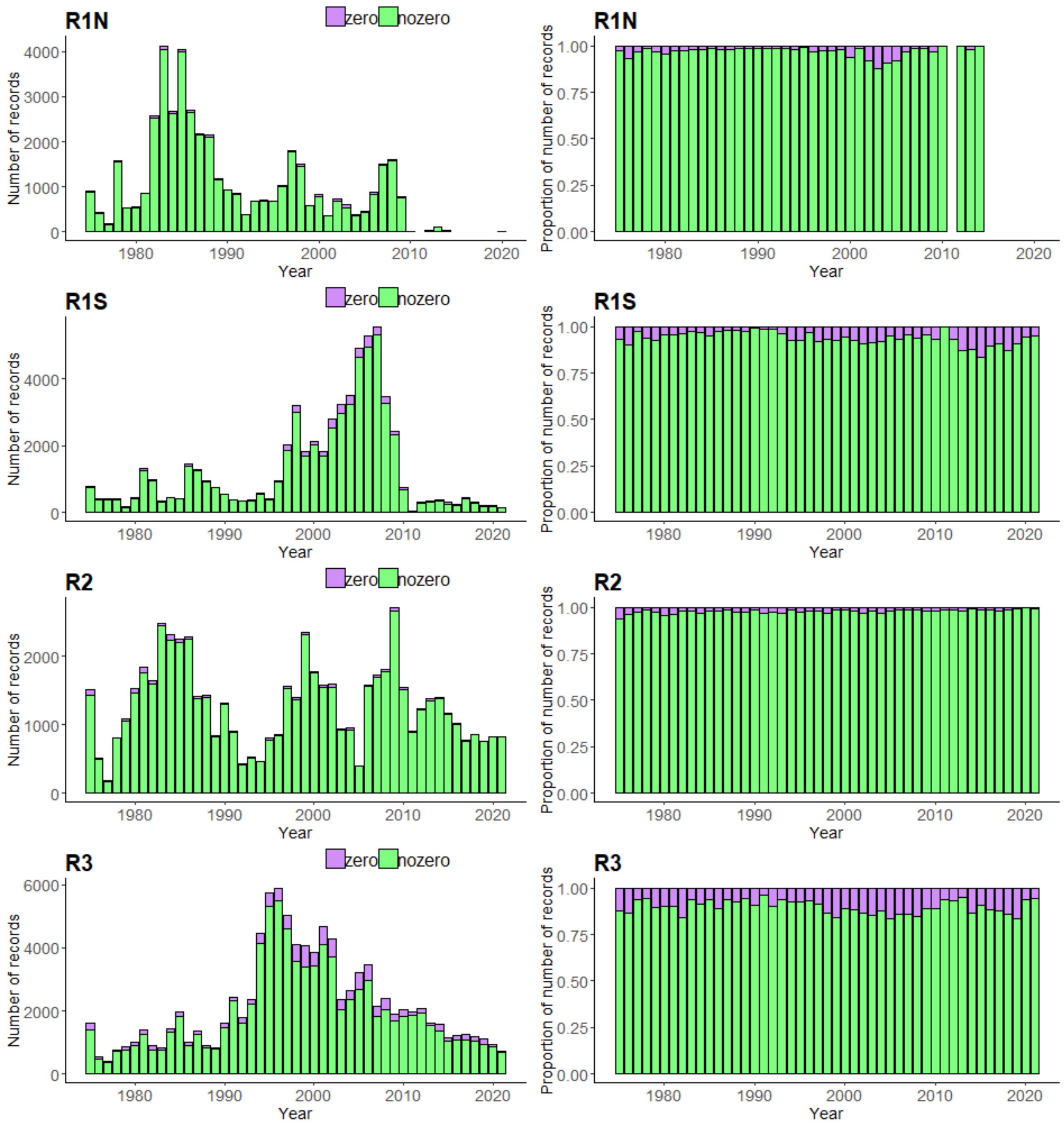
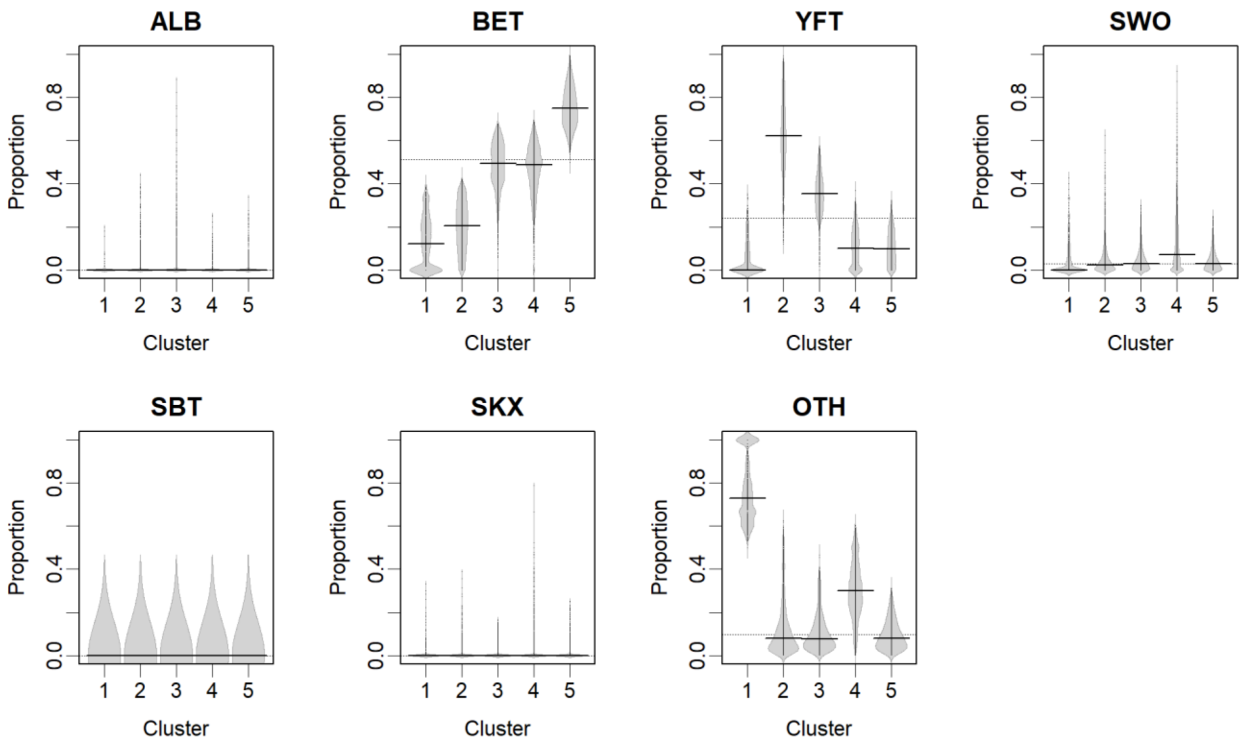


Fig. 3. Number of observations for bigeye tuna zero/non-zero catch in catch-and-effort data used for CPUE standardization.

R1N



R1S

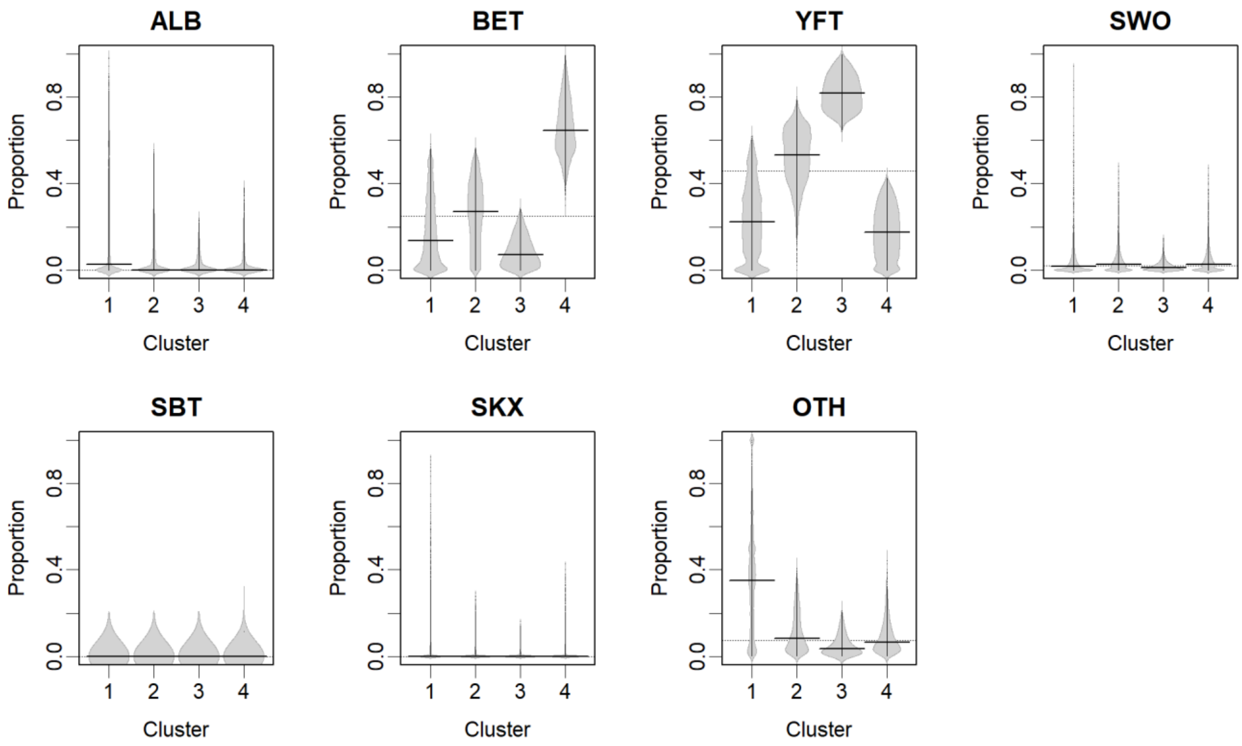
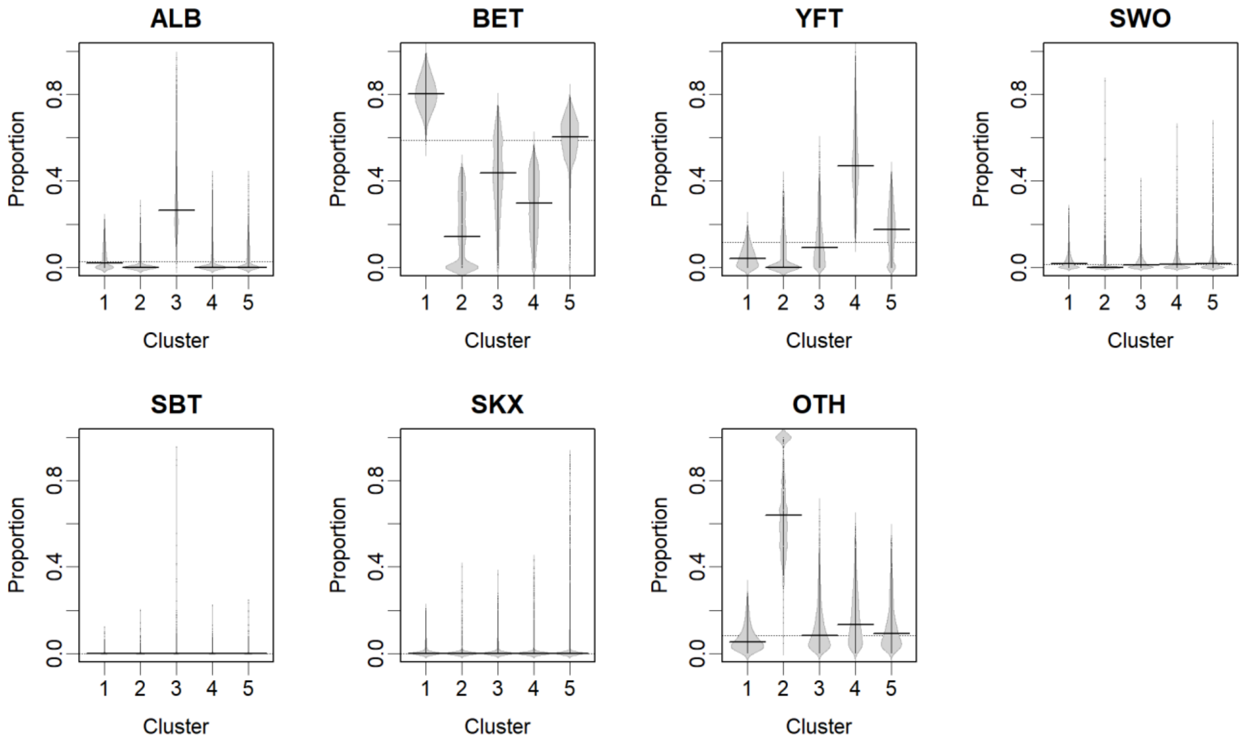


Fig. 4. Beanplots for bigeye tuna region showing species composition by cluster for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH). The horizontal bars indicate the medians.

R2



R3

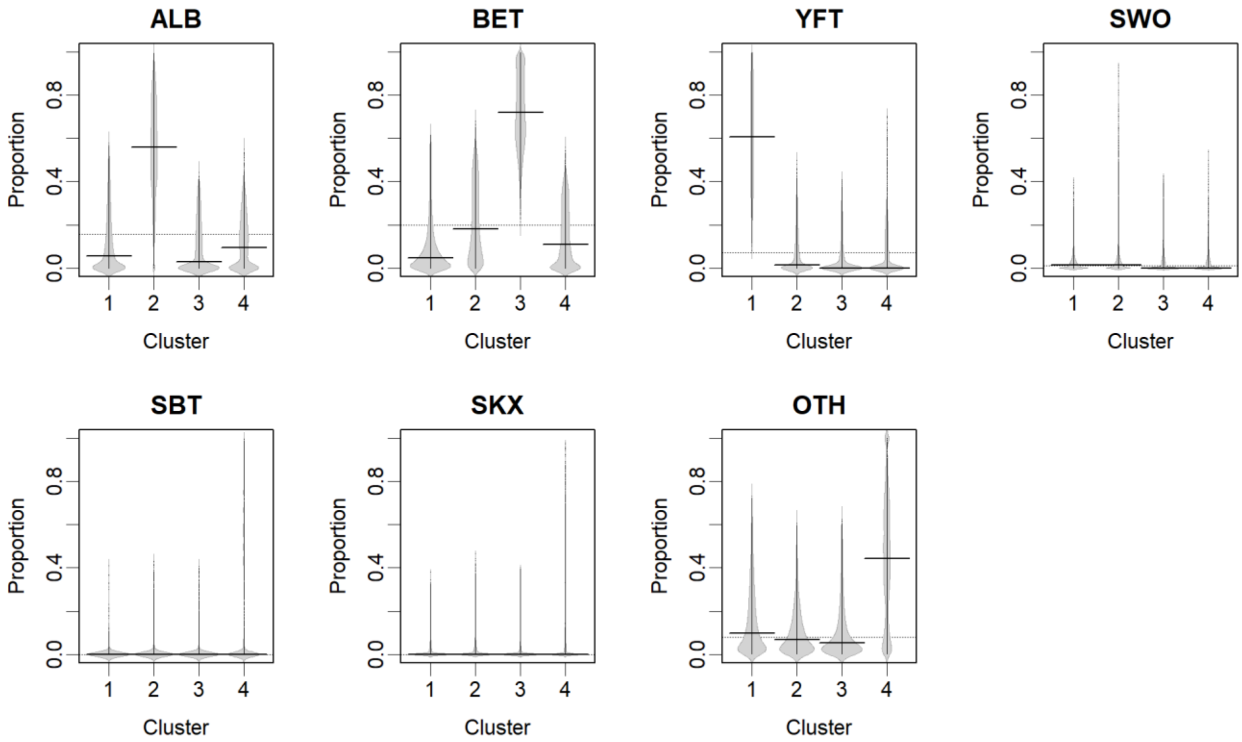


Fig. 4. Beanplots for bigeye tuna region showing species composition by cluster for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH). The horizontal bars indicate the medians. (continued)

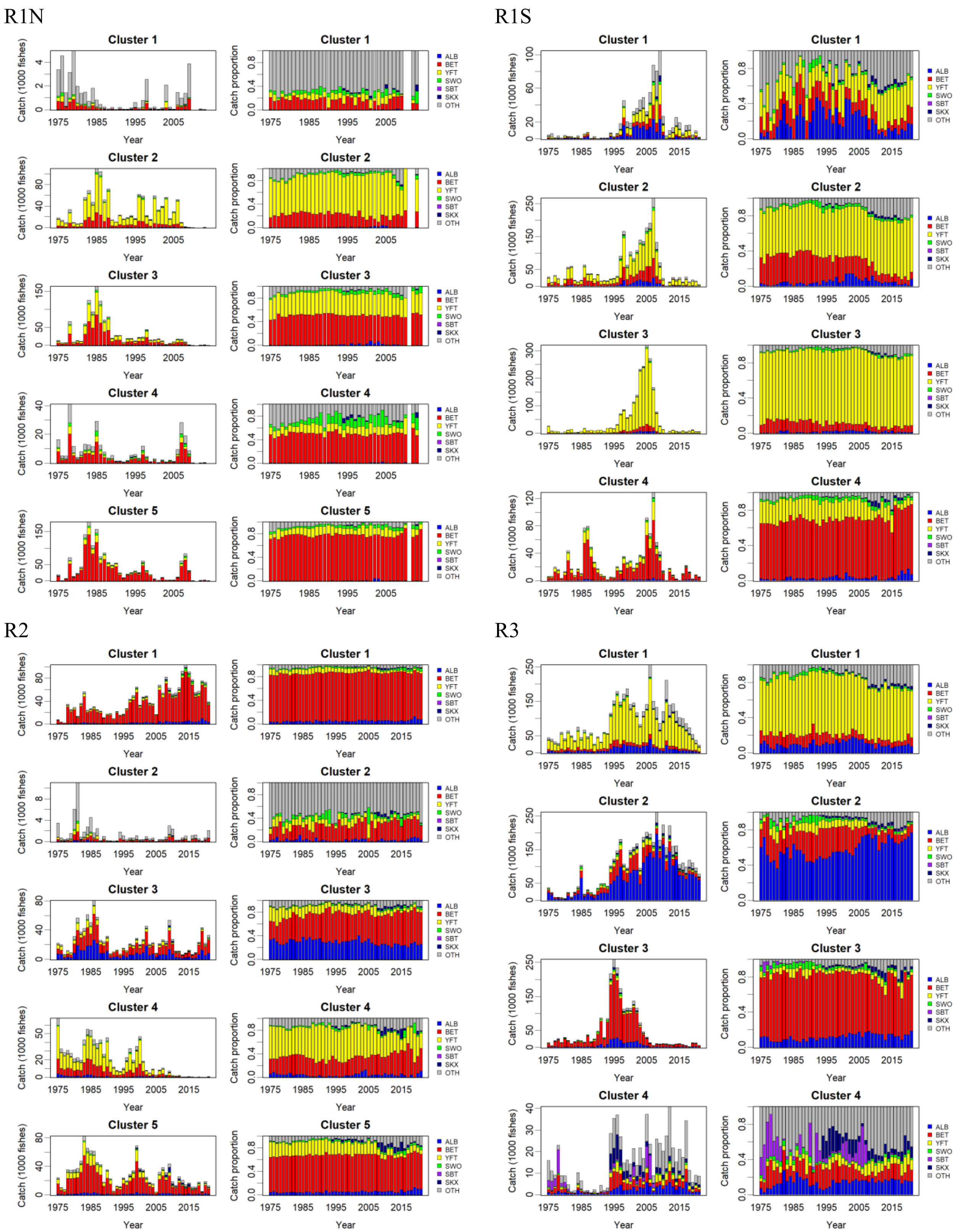


Fig. 5. Annual change in species composition for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), bluefin tuna (BFT), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH) by cluster and area.

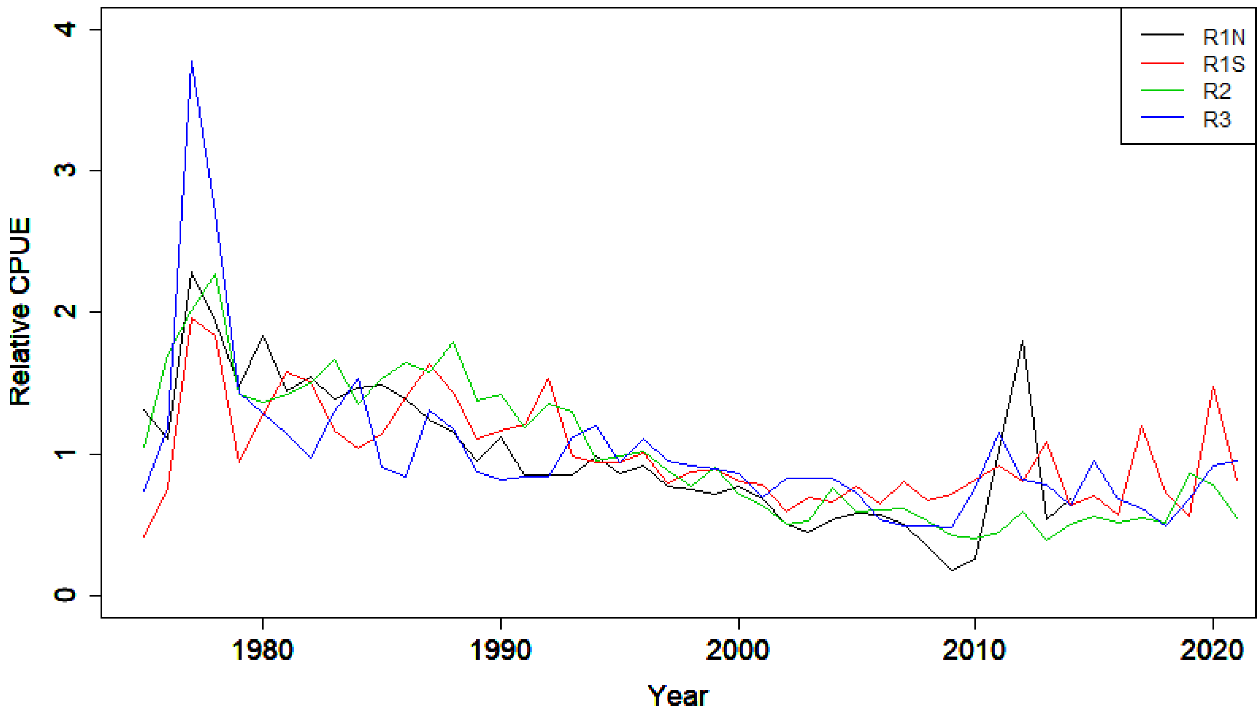


Fig. 6. Standardized year based bigeye tuna CPUE in number for each area.

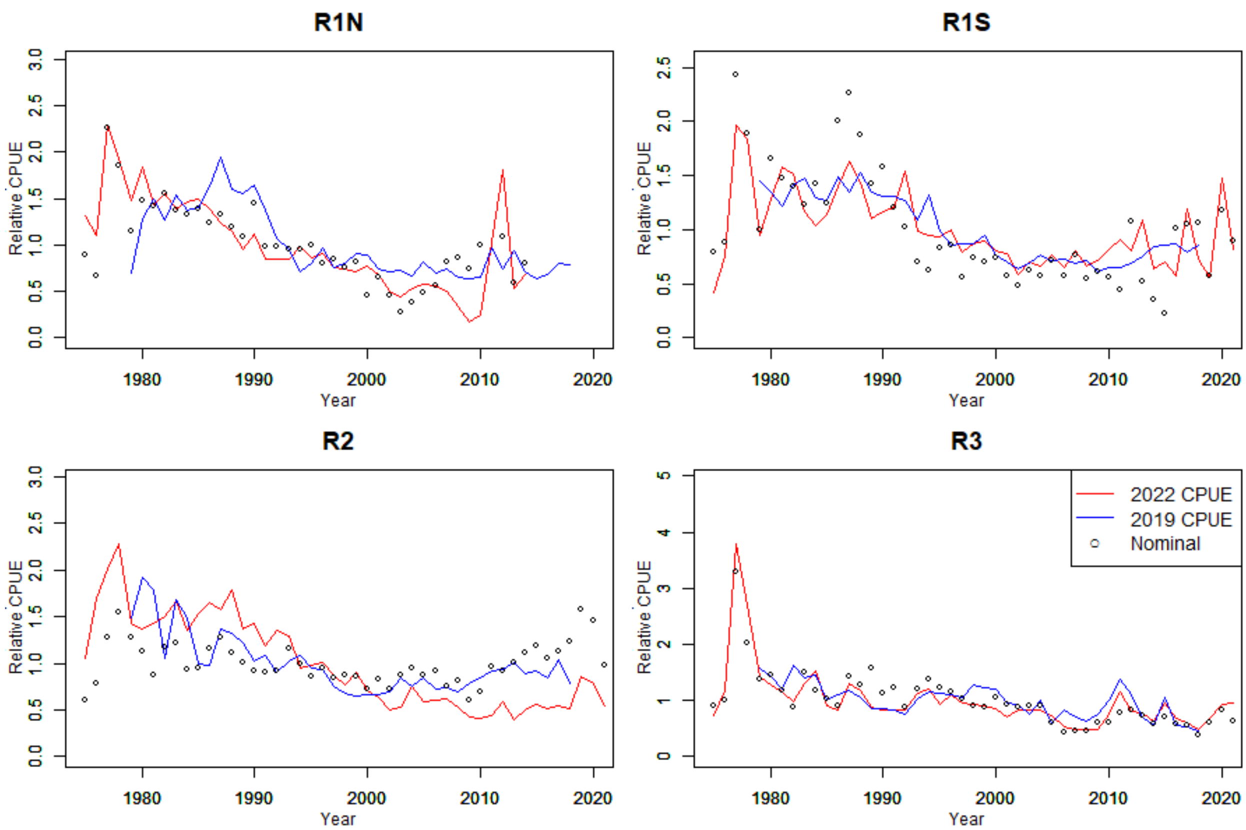


Fig. 7. Standardized year based bigeye tuna CPUE in number for each area (2022 CPUE) with comparison of nominal CPUE and CPUE in the previous study (2019 CPUE: from the previous collaborative study). Note: "R3" for the previous study corresponds to east of 75E for the R3 in this study.

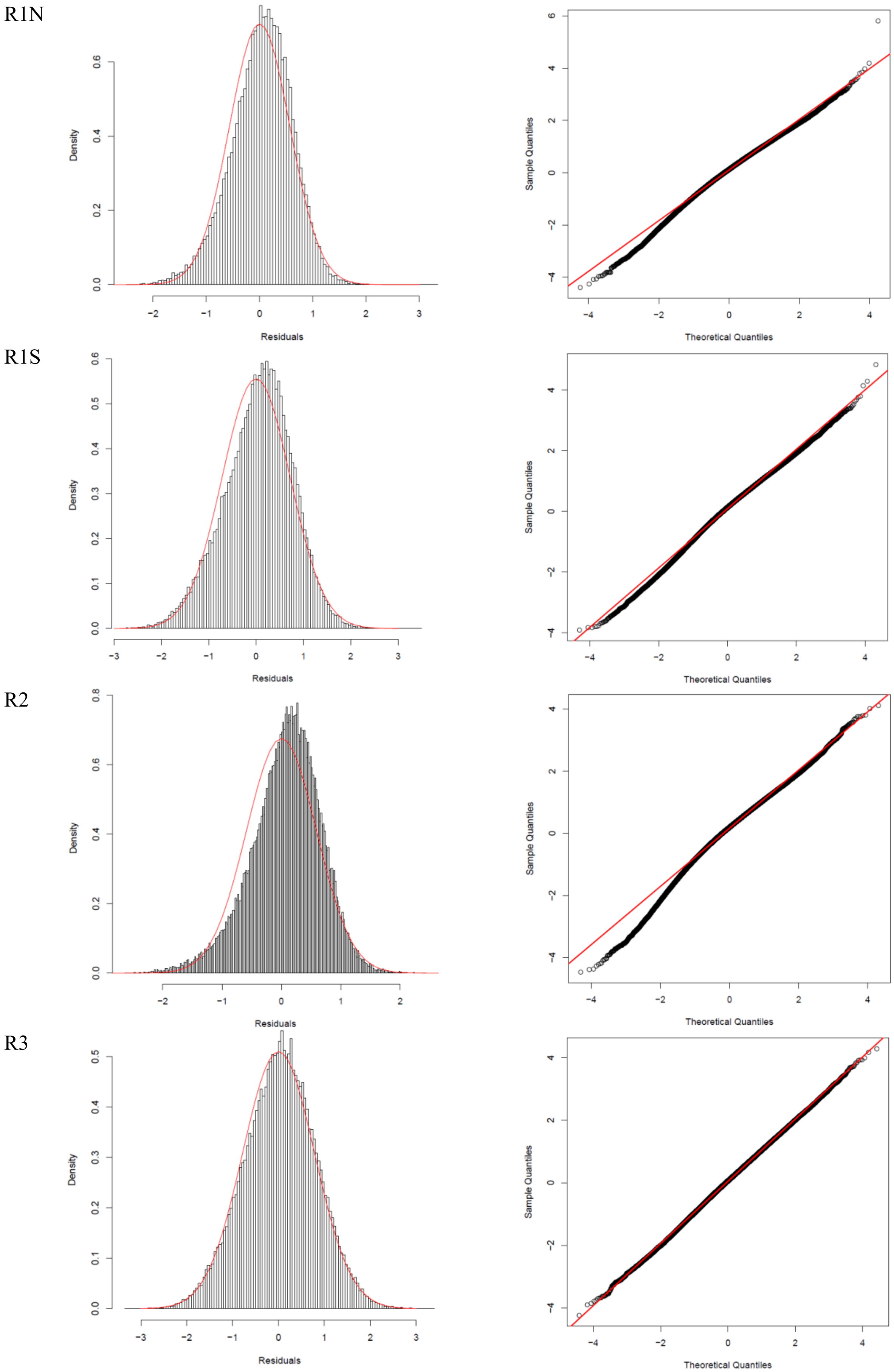


Fig. 8. Standardized residuals of year based CPUE standardization for each of four areas expressed as histograms and QQ plots.

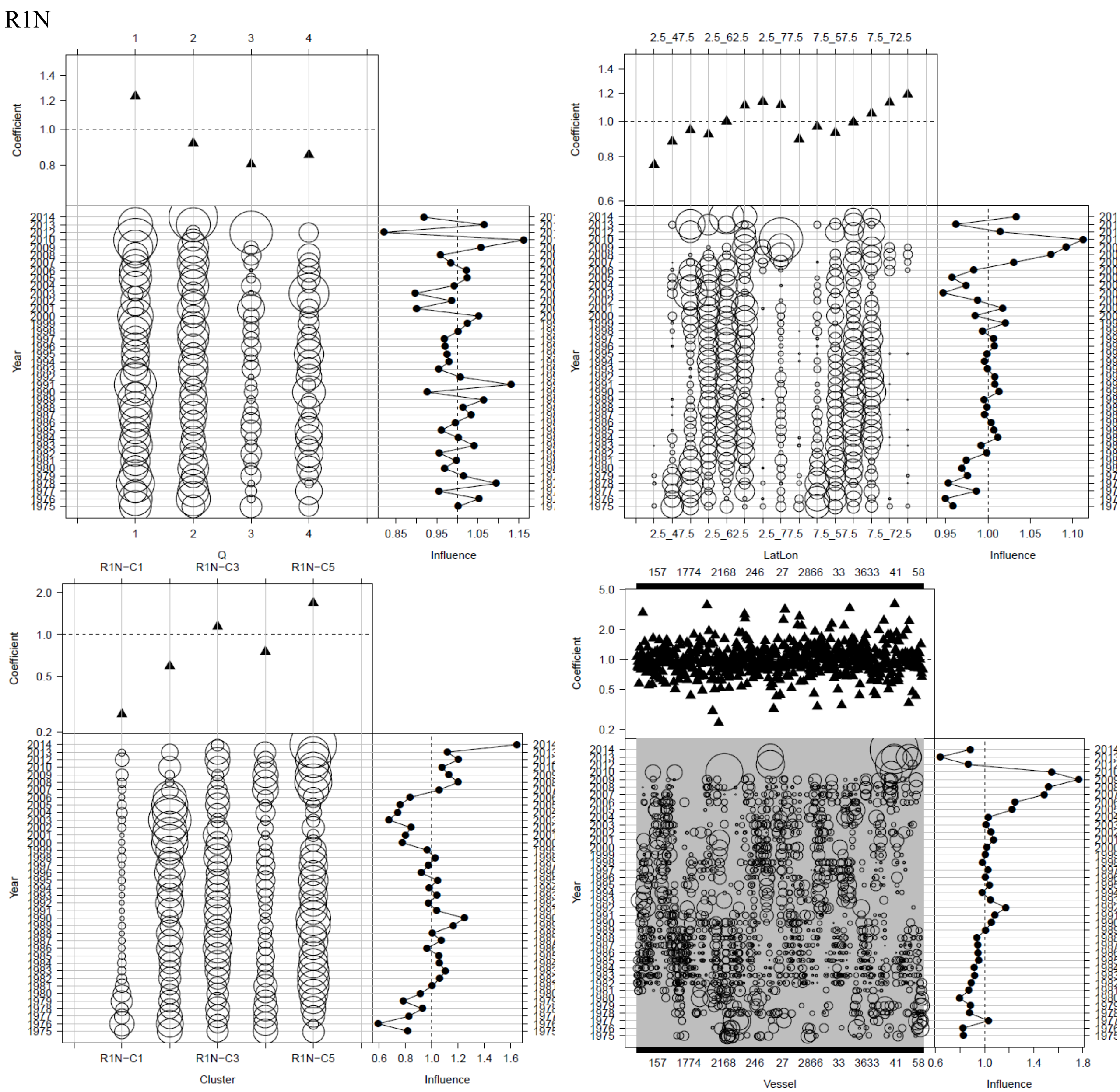


Fig. 9. Influence plot for CPUE standardization for bigeye tuna.

R1S

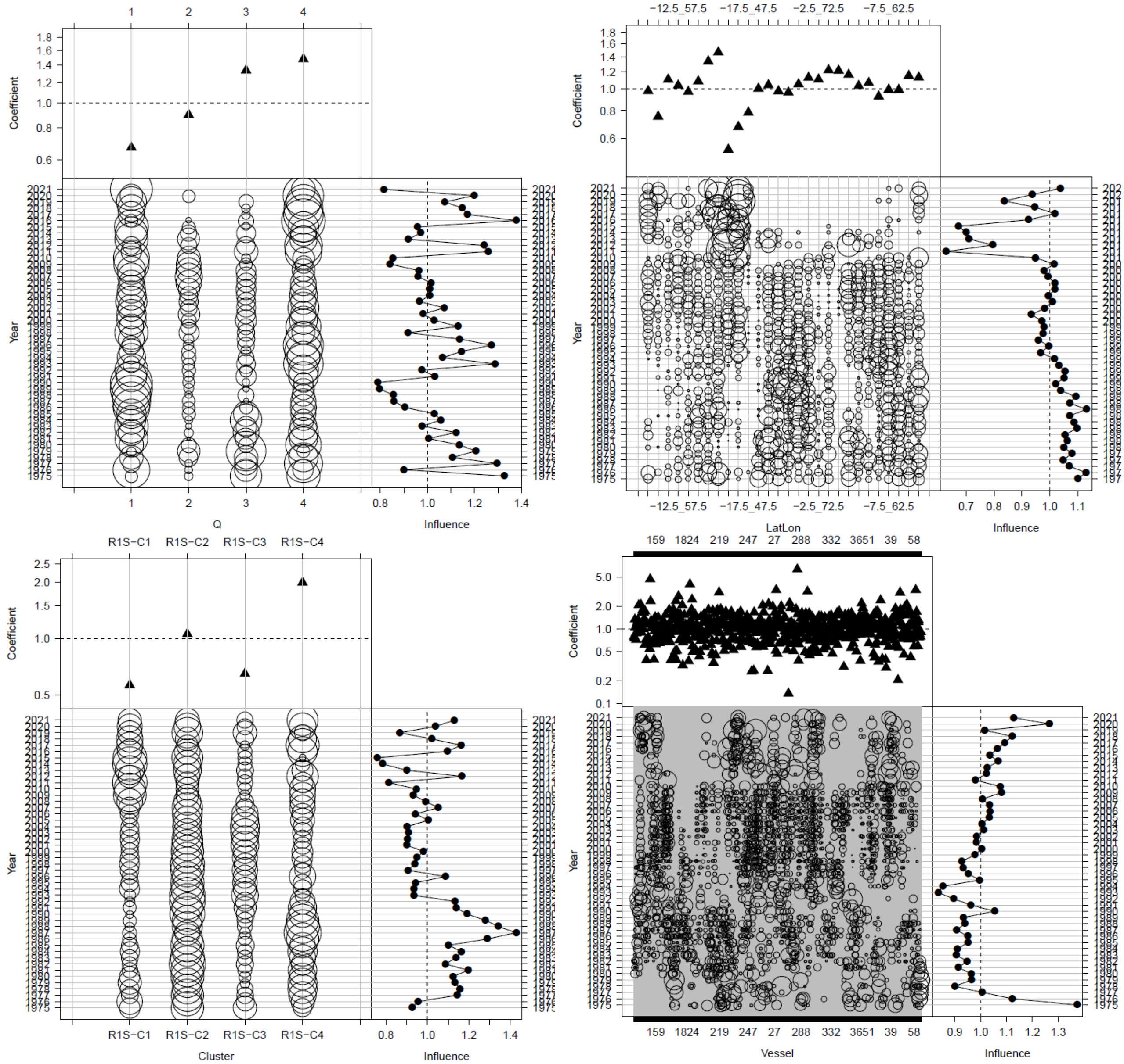


Fig. 9. Influence plot for CPUE standardization for bigeye tuna. **(continued)**

R2

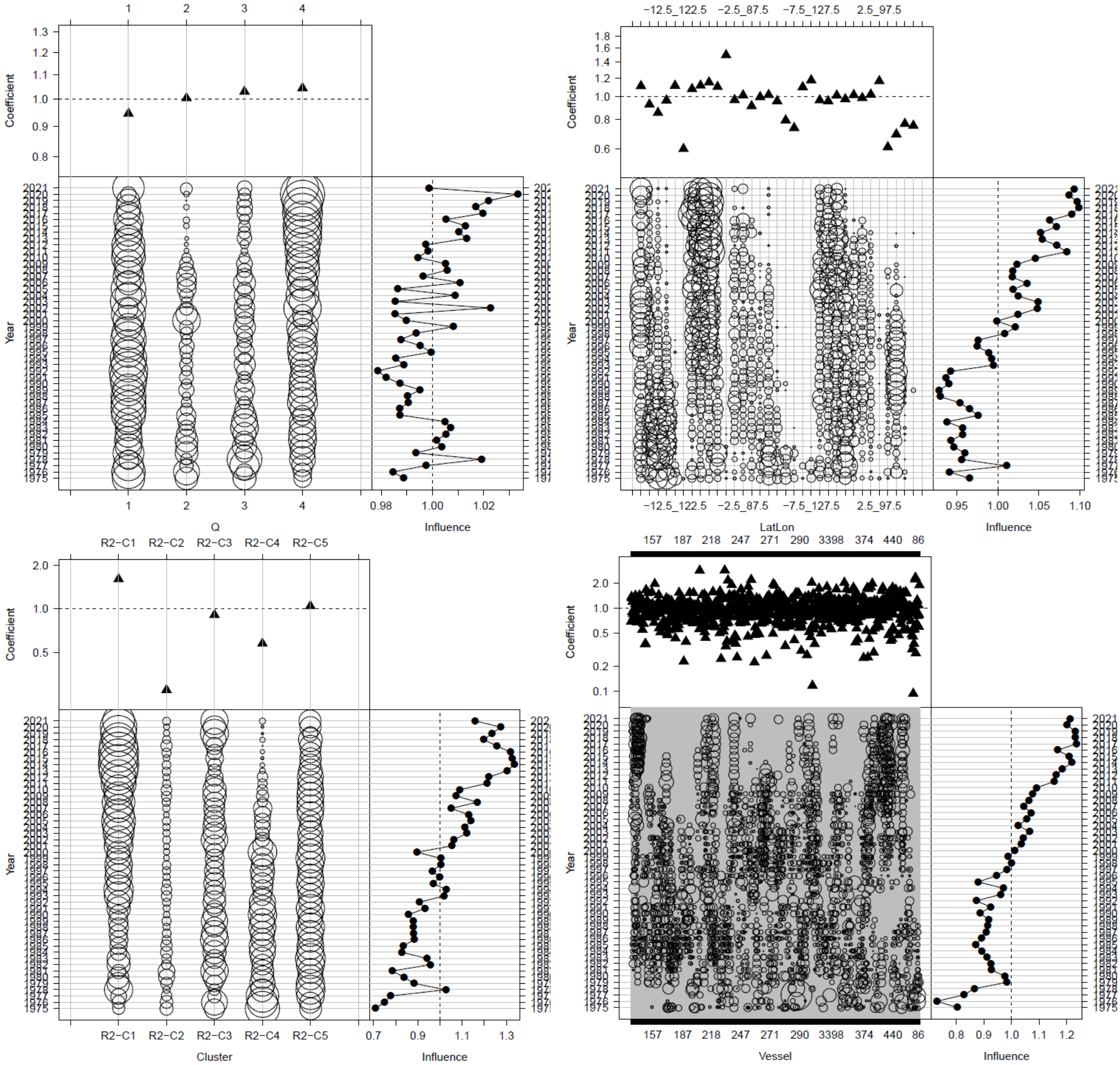


Fig. 9. Influence plot for CPUE standardization for bigeye tuna. **(continued)**

R3

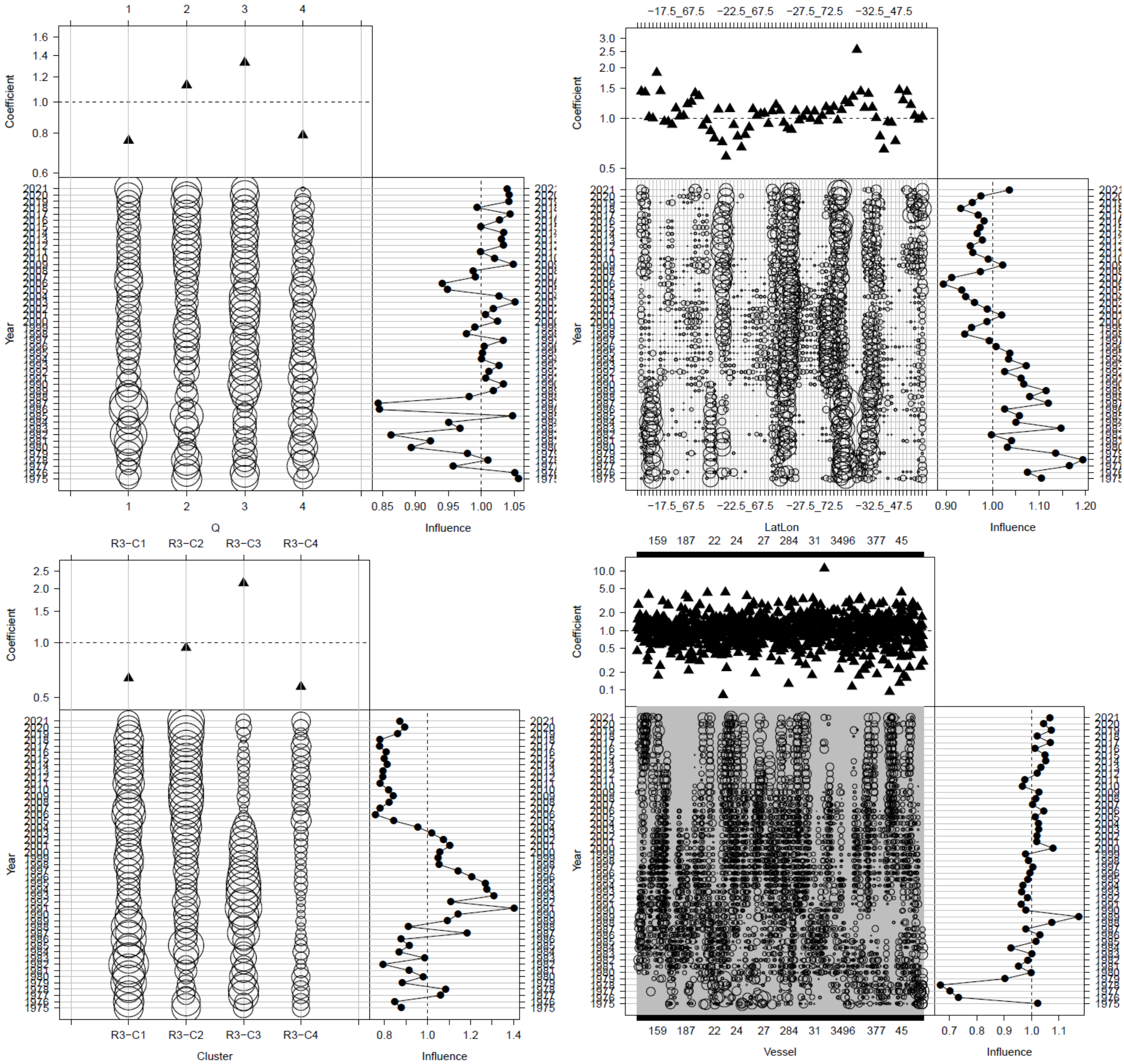
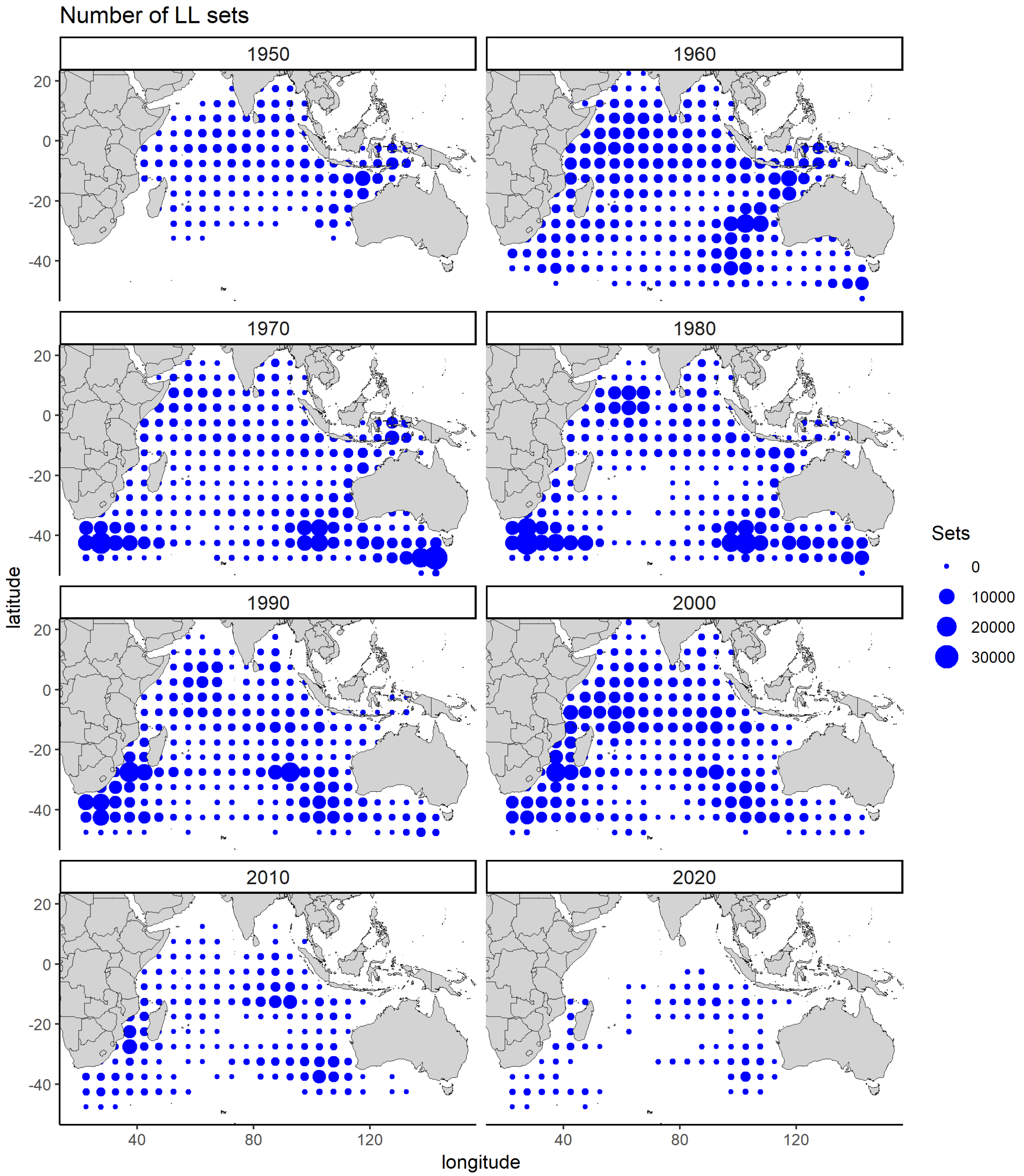
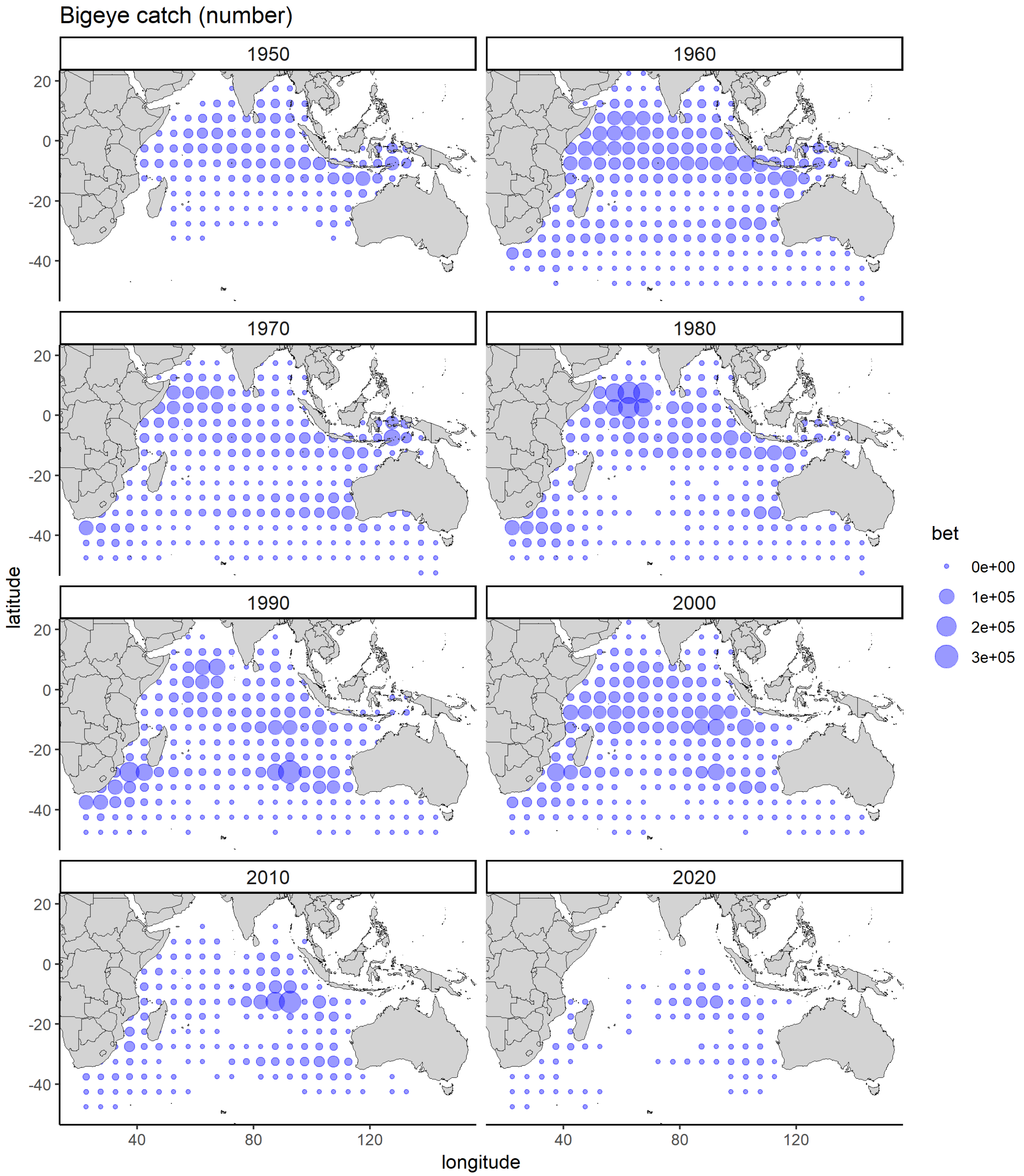


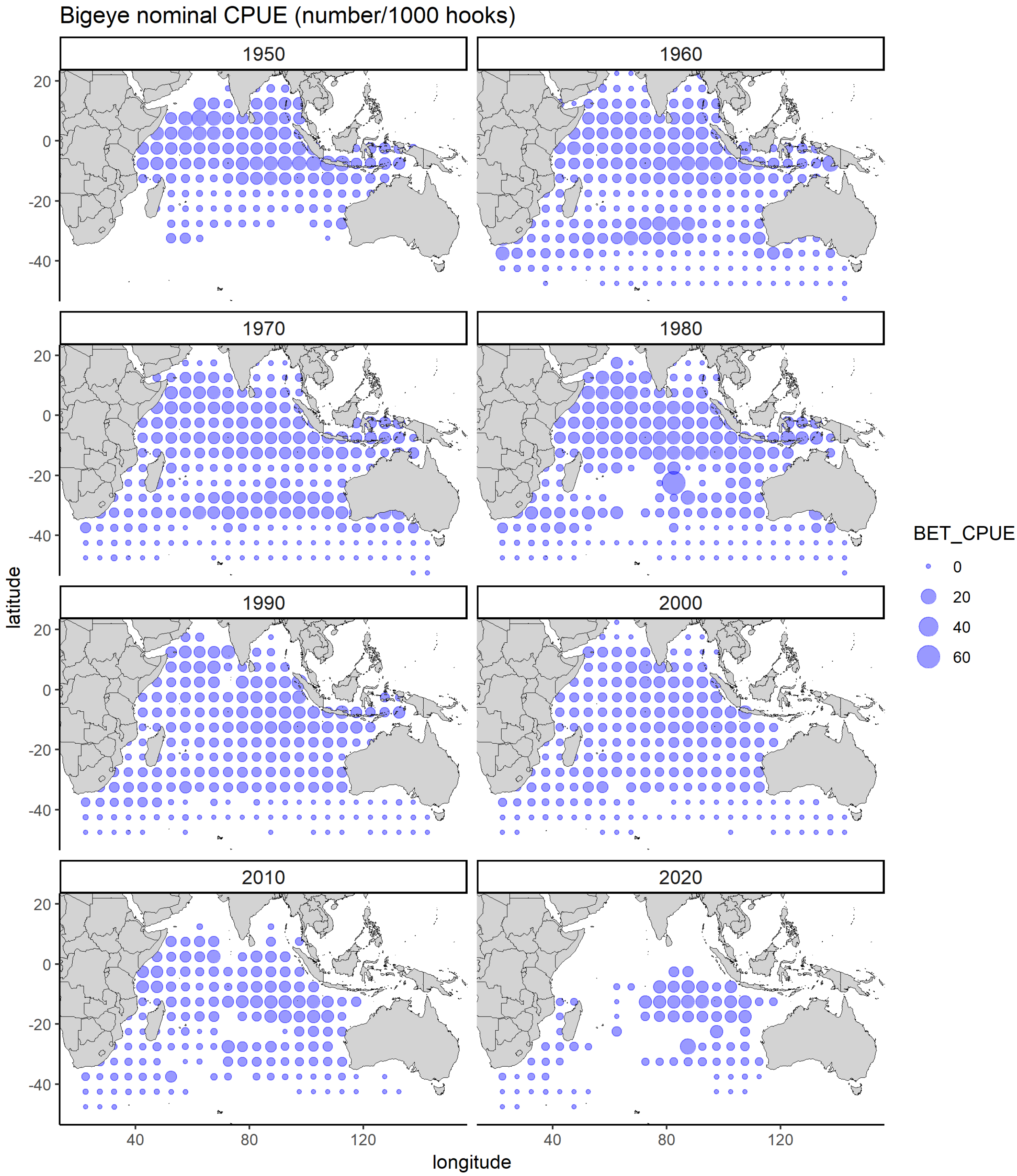
Fig. 9. Influence plot for CPUE standardization for bigeye tuna. **(continued)**



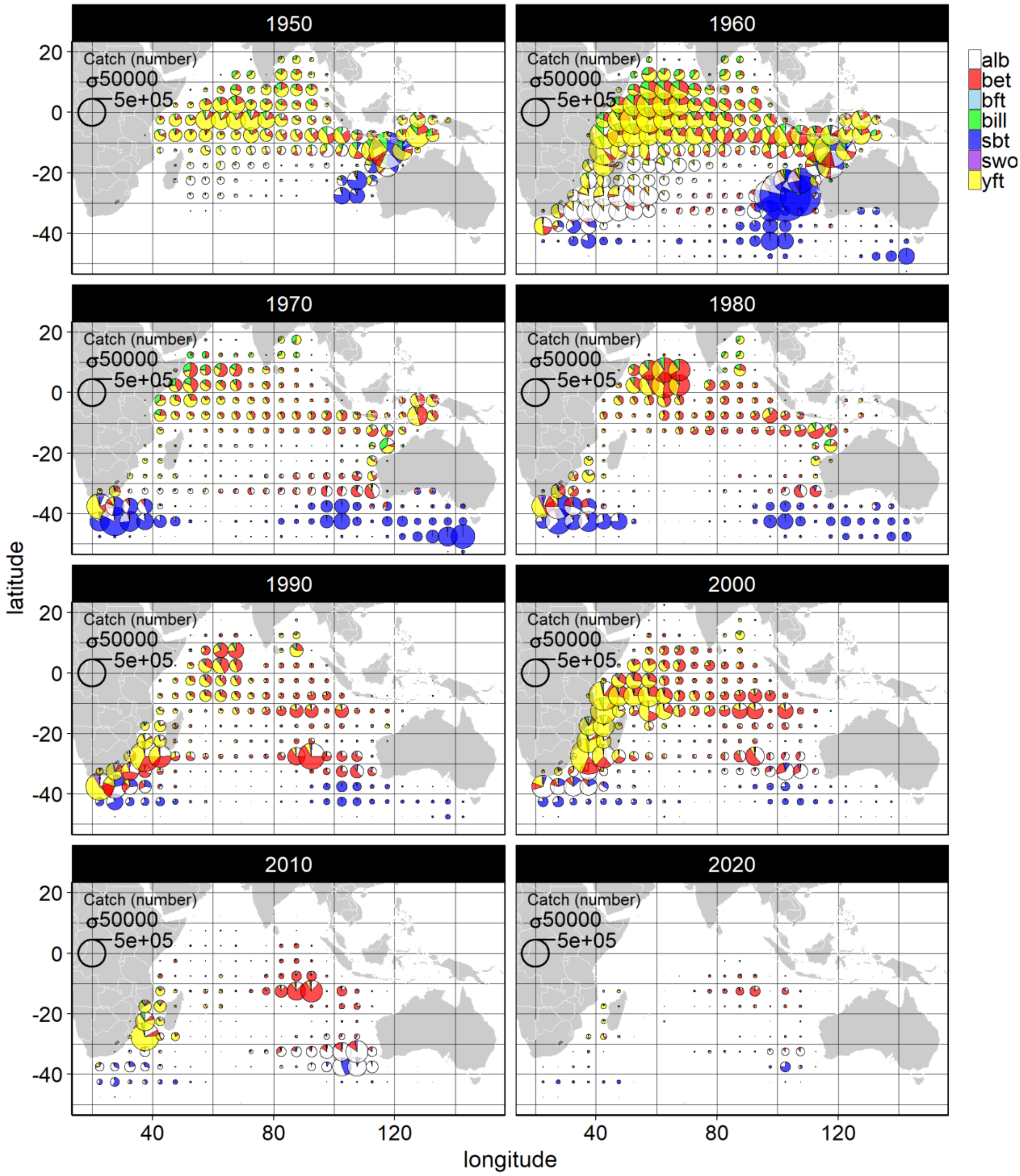
Appendix fig. 1. The distribution of the effort (number of sets) for each decadal period by Japanese longline fishery.



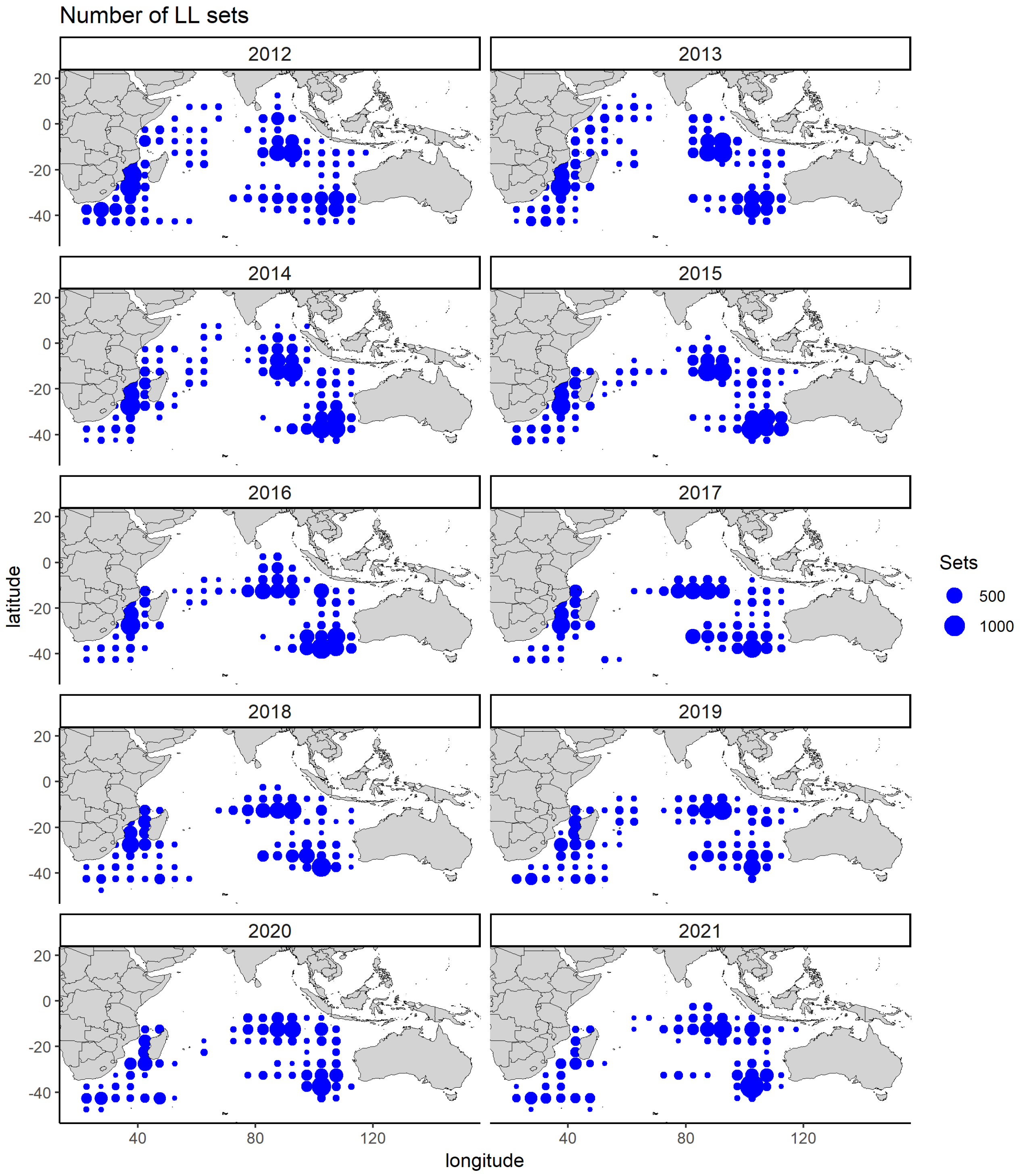
Appendix fig. 2. The distribution of bigeye tuna catch (number of fish) for each decadal period by Japanese longline fishery.



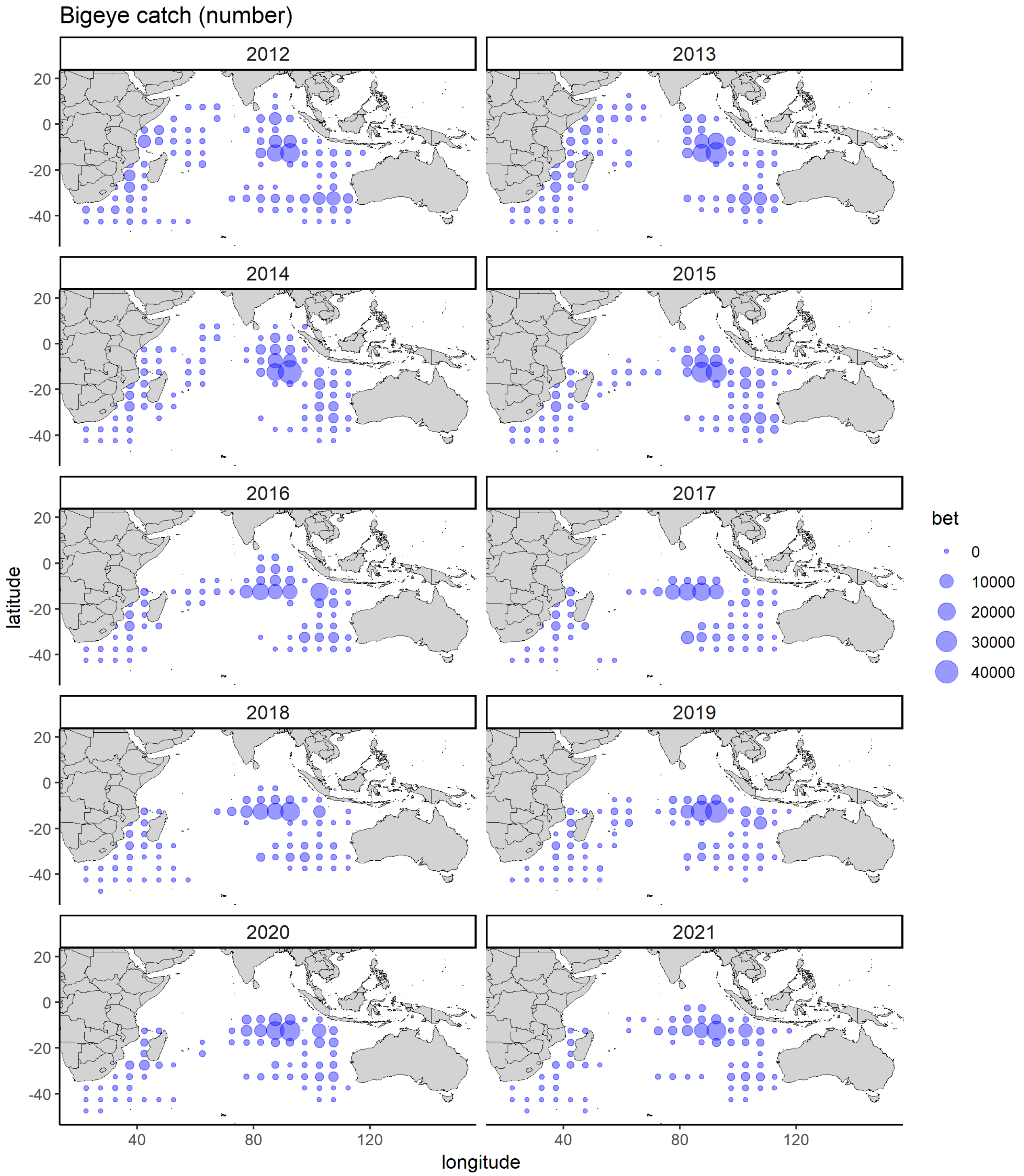
Appendix fig. 3. The average distribution of bigeye tuna CPUE (number of fish/1000 hooks) for each decadal period by Japanese longline fishery.



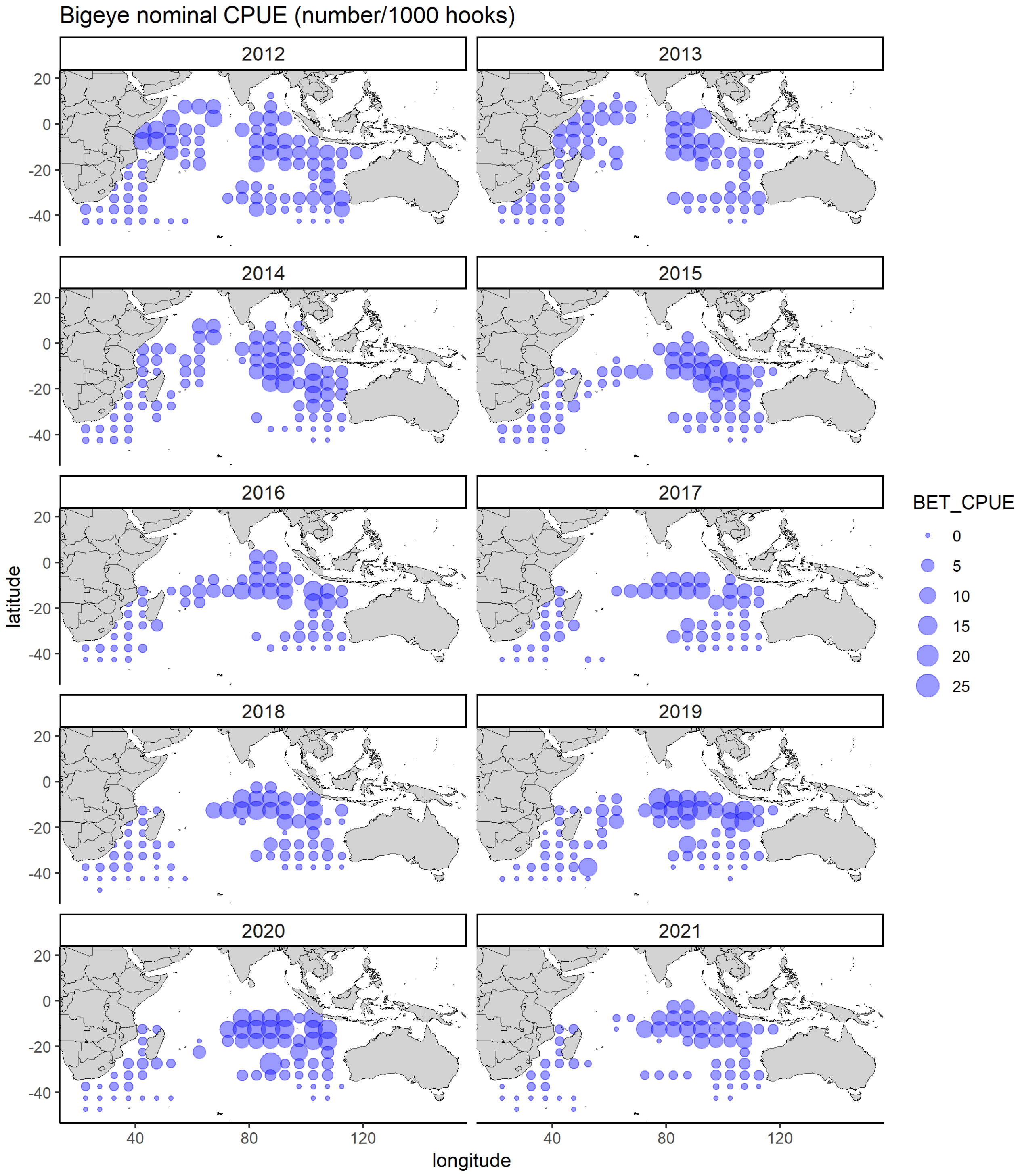
Appendix fig. 4. The distribution of amount of catch in number by species for each decade. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (Bill).



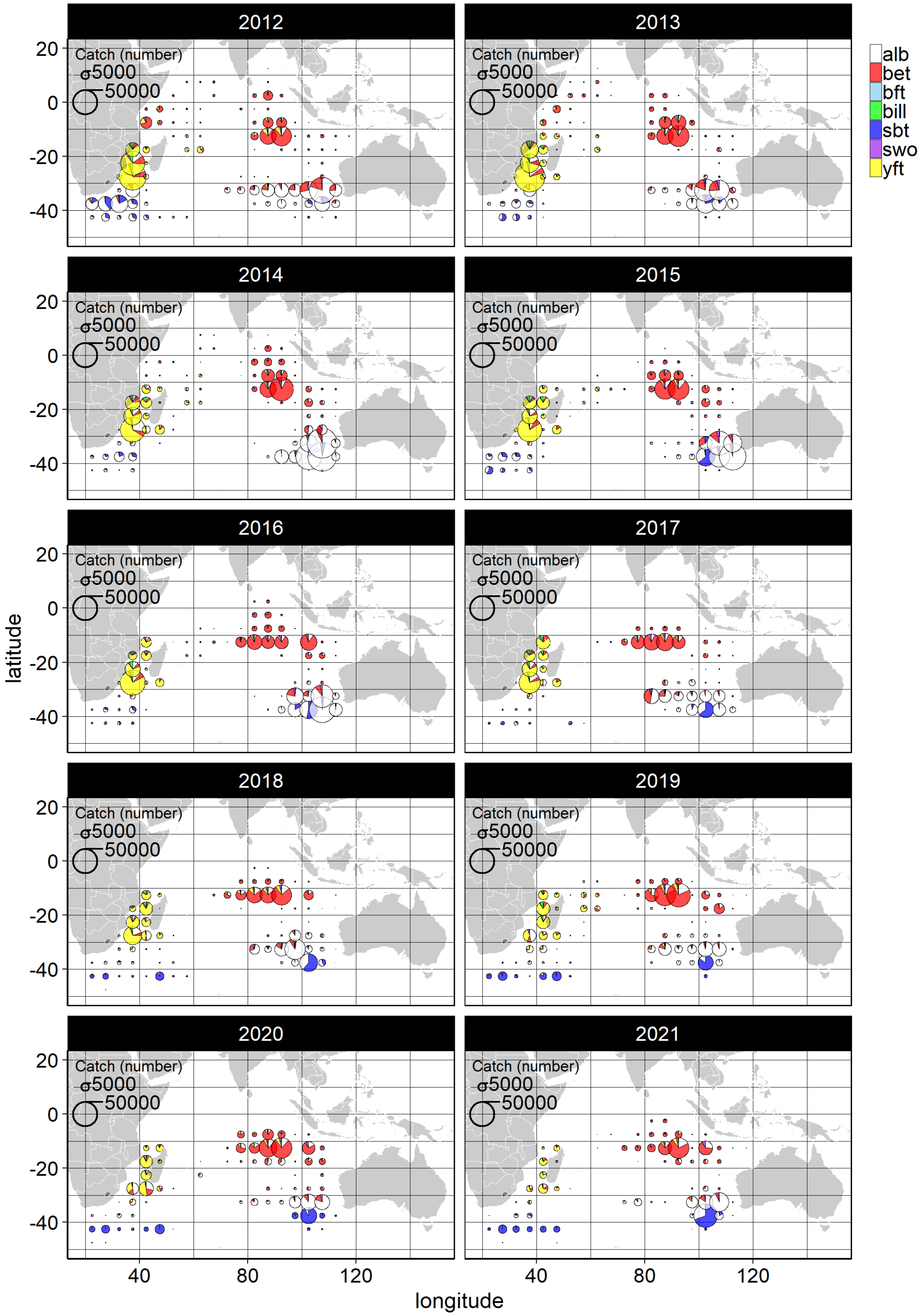
Appendix fig. 5. The geographical distribution of the effort (number of sets) in recent years by Japanese longline fishery.



Appendix fig. 6. The geographical distribution of bigeye tuna catch (number of fish) in recent years by Japanese longline fishery.



Appendix fig. 7. The geographical distribution of bigeye tuna CPUE (number of fish/1000hooks) in recent years by Japanese longline fishery.



Appendix fig. 8. Annual recent distribution of amount of catch in number by species. Size of circle shows amount of total of catches i.e. southern bluefin tuna (SBT), albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO) and billfishes (Bill).