Standardization of albacore CPUE by Japanese longline fishery in the Indian Ocean

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Summary

Standardization of albacore CPUE by Japanese longline fishery in the Indian Ocean was conducted using the Generalized Linear Model (GLM) with lognormal or delta 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 and several interactions. Area definition is the same as that for 2019 IOTC albacore stock assessment. CPUEs slightly increased from early 1990s to early 2010s, and the trend was different among areas after that. The trend of CPUE was usually similar to that in the previous study.

1. INTRODUCTION

Japanese longline fishery commenced in the Indian Ocean in 1952. The fishery caught albacore ranging from 9,000 to 18,000 t in the 1960s that corresponds to the beginning of the long history of the fishery. Since then the catch decreased rapidly and reached to 400 t in 1977. This drastic change is due to the change of target species of the longline fishery, i.e., from yellowfin tuna and albacore to southern bluefin tuna and bigeye tuna, during the 1970s. The catch continued to be in a low level ranging from 400 t to 2,500 t until early 1990s. After that the catch slightly increased and was 6,200 t in 2006, which was highest during the past 40 years. However, it is still about one third of the catch at the peak in 1964. It shows decreasing trend after that. In recent years, although albacore seems to be not a target species by Japanese longline fishery in the Indian Ocean, albacore catch and catch rate are higher than before.

For the Indian Ocean albacore caught by Japanese longline fishery, CPUE standardization using the Generalized Linear Model (GLM) with the assumption that the error structure belongs to log-normal had been carried out for 1960-1991 (Uozumi, 1994) and for 1960-2002 (Uosaki, 2004). Both log-normal and negative binomial error structures were examined by Matsumoto and Uosaki (2011) and Matsumoto et al. (2012) based on aggregated catch and effort data by 5 degree latitude-longitude and operational level data, respectively, considering that negative binomial error structure may be better for standardization of albacore CPUE by Japanese longline which includes certain amount of zero catch data, but log-normal error structure was considered to be better based on information criteria or distribution of the standardized residuals. Therefore, Matsumoto et al. (2014) and Matsumoto and Kitakado (2016) used only log-normal and negative binomial error structure. These are based on so called 'traditional method'. In May to June 2018, IOTC joint CPUE analysis was conducted and joint standardized CPUEs for albacore were created using operational level data for Japanese, Korean and Taiwanese longline fishery combined, as well as Japanese longline CPUE by the same method (IOTC, 2018, 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 2019 by Japanese, Korean and Taiwanese scientists has been conducted and the results of CPUE standardization for Indian Ocean yellowfin tuna (joint CPUE and each fleet CPUE) was reported (Kitakado et al., 2021a,b, Matsumoto et al., 2021). 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, the same approach has been applied for CPUE standardization of Indian Ocean albacore caught by Japanese longline fishery. One of the objectives of this study is to compare CPUE indices with those by the previous CPUE analysis.

2.MATERIALS AND METHODS

The methods to standardize CPUE are basically the same as conventional regression analyses in the CPUE collaborative study mentioned above (Kitakado et al., 2021a,b, Matsumoto et al., 2021).

Catch and effort data

Operational level (set by set) Japanese longline logbook data with vessel ID were used. The data were available for 1975-2020. 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 those in the previous (2019) IOTC stock assessment of albacore. Fig. 2 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. (2021 a,b), 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 delta lognormal analyses was basically conducted because zero catch ratio is high in a part of aera and period (Fig. 2), and negative values of CPUE indices occurred as a result of lognormal model. However, if no reasonable results were obtained based on delta lognormal model, lognormal model was used in that area. The following initial (full) models were used:

Delta lognormal

$g(w) = (CPUE = 0) \sim year + q + vessel + latlon5 + cluster + \ yr * q + cluster * q + \epsilon$, where g is the logistic function.

$f(y) = CPUE \sim \ year + q + vessel + latlon5 + cluster + \ yr * q + cluster * q + \epsilon$

Lognormal

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

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; cluster $*q$: interaction between cluster 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 which are not significant (at 1% level) were eliminated. 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. 3**) and each region and year (**Fig. 4**). Dominant species differed depending on clusters, but there was at least one cluster in each region in which albacore was dominant. Number of clusters were 4 or 5 for each region.

The results for ANOVA (type 2) are shown in Table **1**. As for area 4, reasonable results were obtained only for lognormal model without interaction. For other areas, the results of delta lognormal model with interactions were adopted. Fig. 5 shows comparison of albacore CPUE by area, and Fig. 6 shows comparison of albacore 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, but there is some difference in the early and recent periods. CPUEs show slight increasing trend from early 1990s to early 2010s, and the trend is different among areas after that. For example, decreasing trend is observed for area 1, and there is high jump and the sharp decrease in area 4. The trend of CPUE in this study is usually similar to those in the previous study.

Fig. 7 shows distribution of standardized residuals and QQ plots. It seems that the distributions are not largely skewed, but slight skew is seen for area 4. **Fig. 8** shows influence plots. In many 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 area 2, although it is increasing in area 4.

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

R1

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Analysis of Deviance Table (Type II tests)

Response: log(CPUE)
          LR Chisq  Df Pr(>Chisq)
Year        1047.1  45  < 2.2e-16 ***
Q            461.0   3  < 2.2e-16 ***
LatLon       949.7  23  < 2.2e-16 ***
Cluster     8427.0   4  < 2.2e-16 ***
Vessel      3949.3 434  < 2.2e-16 ***
Q:Cluster    353.7  12  < 2.2e-16 ***
Year:Q      1063.9 110  < 2.2e-16 ***
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Analysis of Deviance Table (Type II tests)

Response: CPUE != 0
          LR Chisq  Df Pr(>Chisq)
Year         554.7  45  < 2.2e-16 ***
Q            206.3   3  < 2.2e-16 ***
LatLon       499.5  23  < 2.2e-16 ***
Cluster     3021.1   4  < 2.2e-16 ***
Vessel      3317.2 509  < 2.2e-16 ***
Q:Cluster     96.0  12  3.318e-15 ***
Year:Q       732.2 117  < 2.2e-16 ***
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R2

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Analysis of Deviance Table (Type II tests)

Response: log(CPUE)
          LR Chisq  Df Pr(>Chisq)
Year        1165.0  45  < 2.2e-16 ***
Q            171.3   3  < 2.2e-16 ***
LatLon      1277.0  28  < 2.2e-16 ***
Cluster    14618.9   3  < 2.2e-16 ***
Vessel      6641.9 719  < 2.2e-16 ***
Q:Cluster     80.9   9  1.093e-13 ***
Year:Q      1886.4 132  < 2.2e-16 ***
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Analysis of Deviance Table (Type II tests)

Response: CPUE != 0
          LR Chisq  Df Pr(>Chisq)
Year         837.4  45  < 2.2e-16 ***
Q            111.3   3  < 2.2e-16 ***
LatLon       802.5  29  < 2.2e-16 ***
Cluster     4524.6   3  < 2.2e-16 ***
Vessel      5127.2 783  < 2.2e-16 ***
Q:Cluster     40.1   9  7.257e-06 ***
Year:Q       875.5 133  < 2.2e-16 ***
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R3

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Analysis of Deviance Table (Type II tests)

Response: log(CPUE)
          LR Chisq  Df Pr(>Chisq)
Year        1412.3  45  < 2.2e-16 ***
Q           1900.4   3  < 2.2e-16 ***
LatLon      2542.5  30  < 2.2e-16 ***
Cluster    27436.9   4  < 2.2e-16 ***
Vessel      8835.9 714  < 2.2e-16 ***
Q:Cluster    614.6  12  < 2.2e-16 ***
Year:Q      2424.9 135  < 2.2e-16 ***
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Analysis of Deviance Table (Type II tests)

Response: CPUE != 0
          LR Chisq  Df Pr(>Chisq)
Year        1582.5  45  < 2.2e-16 ***
Q            303.6   3  < 2.2e-16 ***
LatLon       936.6  30  < 2.2e-16 ***
Cluster    15479.8   4  < 2.2e-16 ***
Vessel     10976.9 788  < 2.2e-16 ***
Q:Cluster     67.2  12  1.082e-09 ***
Year:Q      1209.6 135  < 2.2e-16 ***
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R4

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Analysis of Deviance Table (Type II tests)

Response: log(CPUE + const)
        LR Chisq  Df Pr(>Chisq)
Year        2909  45  < 2.2e-16 ***
Q           2126   3  < 2.2e-16 ***
LatLon      1961  32  < 2.2e-16 ***
Cluster    68565   4  < 2.2e-16 ***
Vessel     16559 786  < 2.2e-16 ***
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Significance level: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

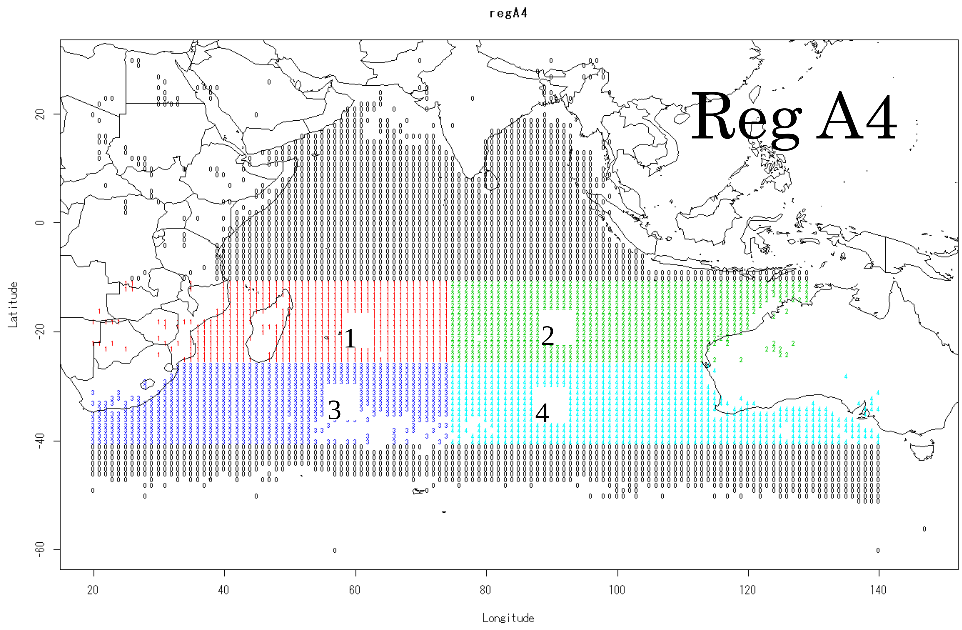


Fig. 1. Area used for the GLM analysis.

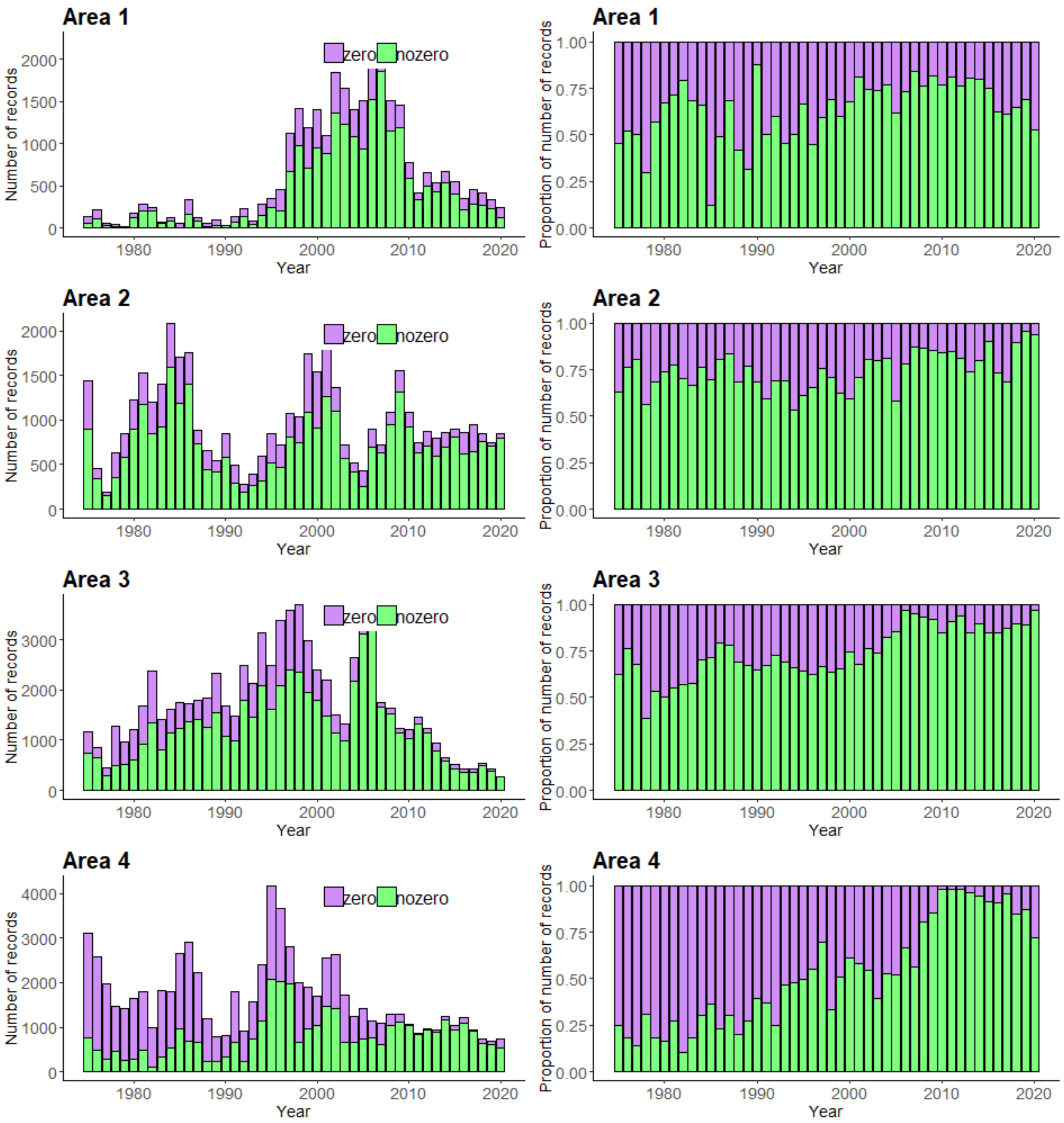
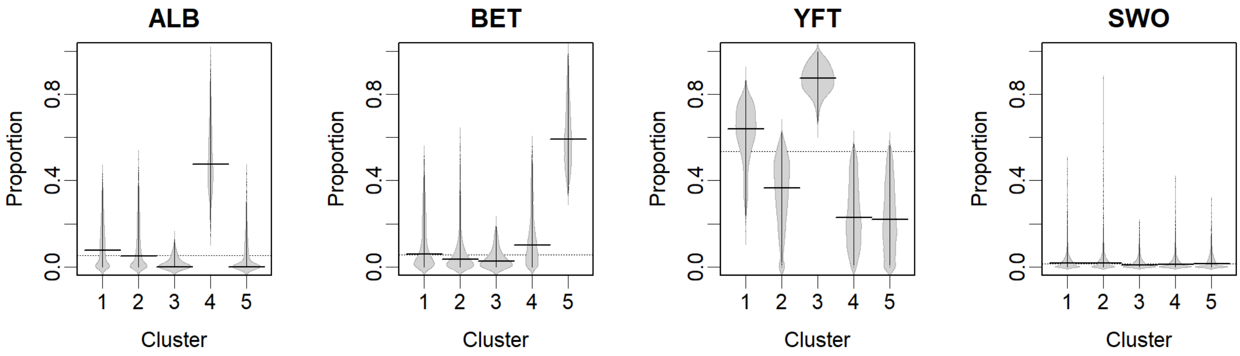


Fig. 2. Number of observations for albacore zero/non-zero catch in catch-and-effort data used for CPUE standardization.

R1



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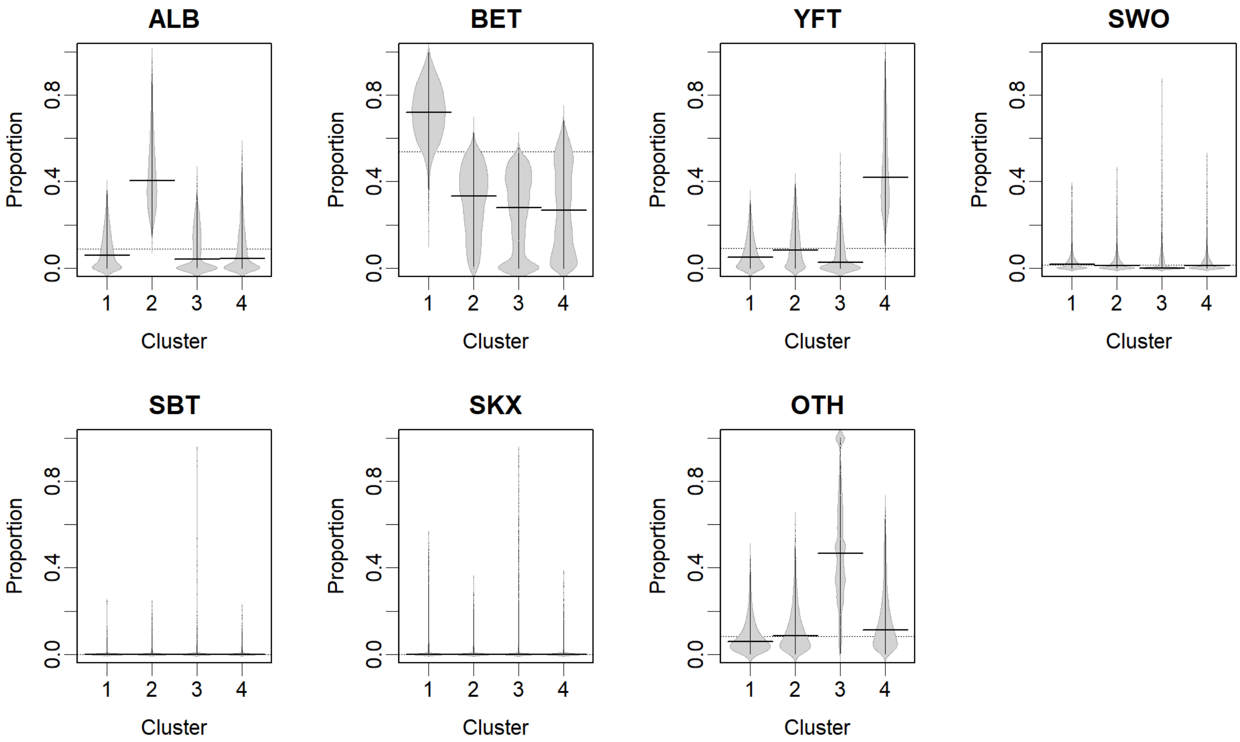
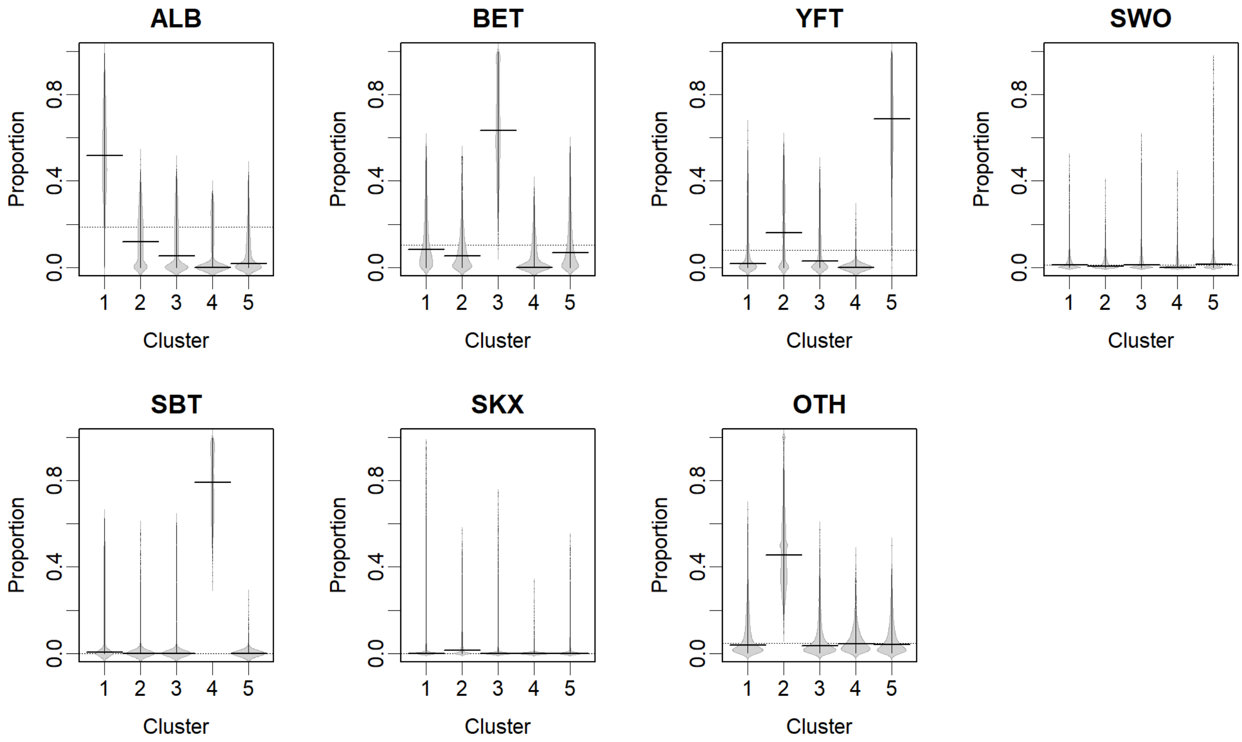


Fig. 3. Beanplots for albacore region showing species composition by cluster for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH). The horizontal bars indicate the medians.

R3



R4

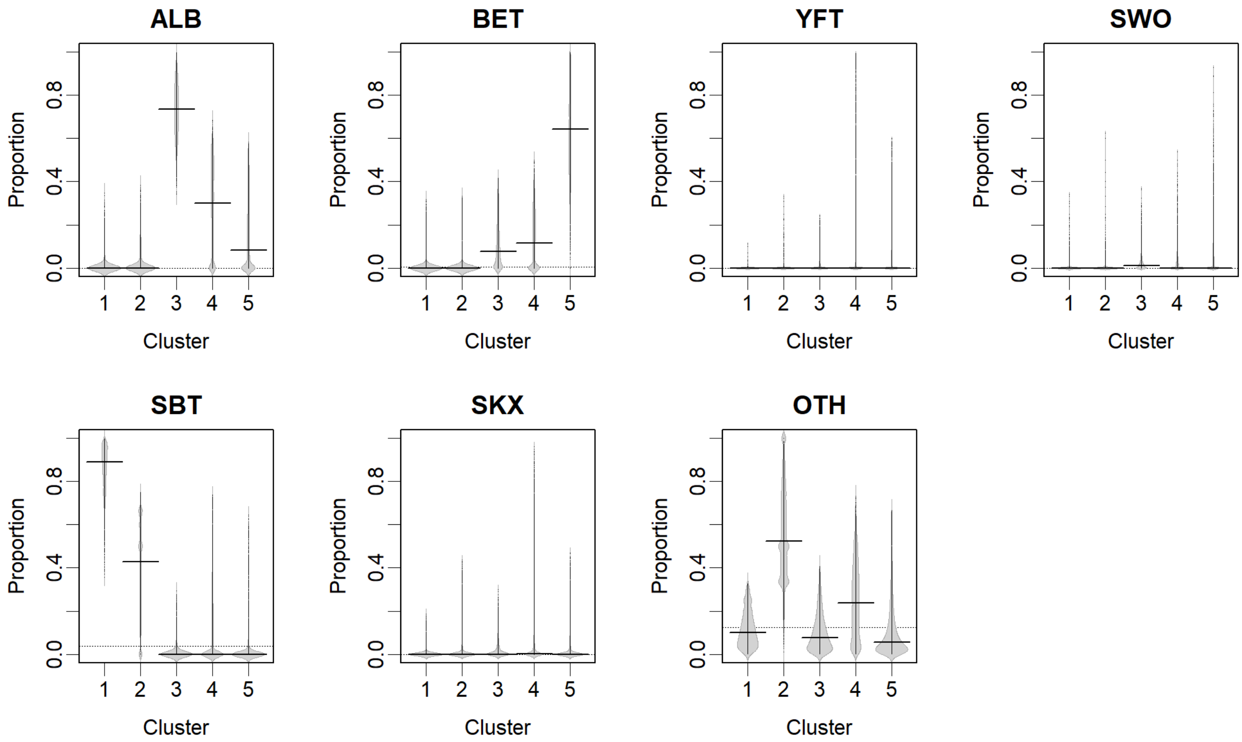


Fig. 3. Beanplots for albacore region showing species composition by cluster for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH). The horizontal bars indicate the medians. (continued)

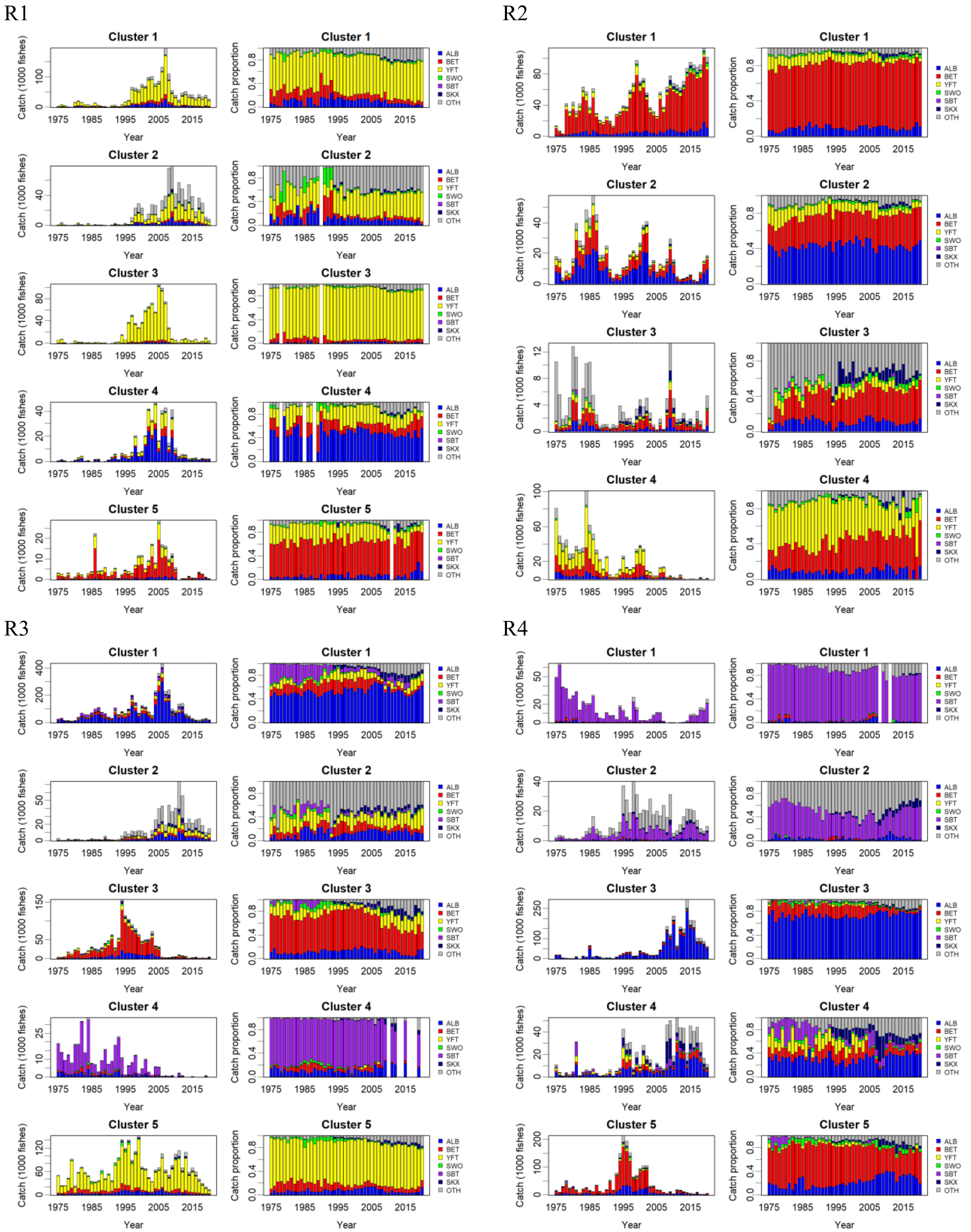


Fig. 4. Annual change in species composition for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), bluefin tuna (BFT), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH) by cluster and area.

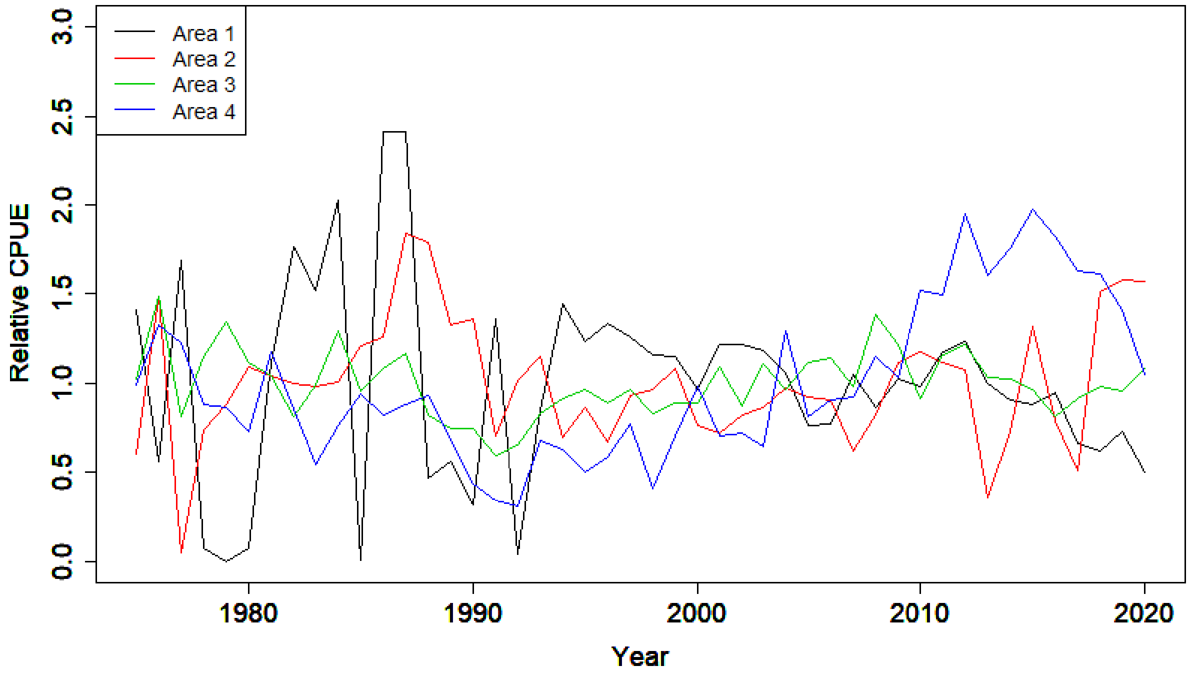


Fig. 5. Standardized year based CPUE in number for each area.

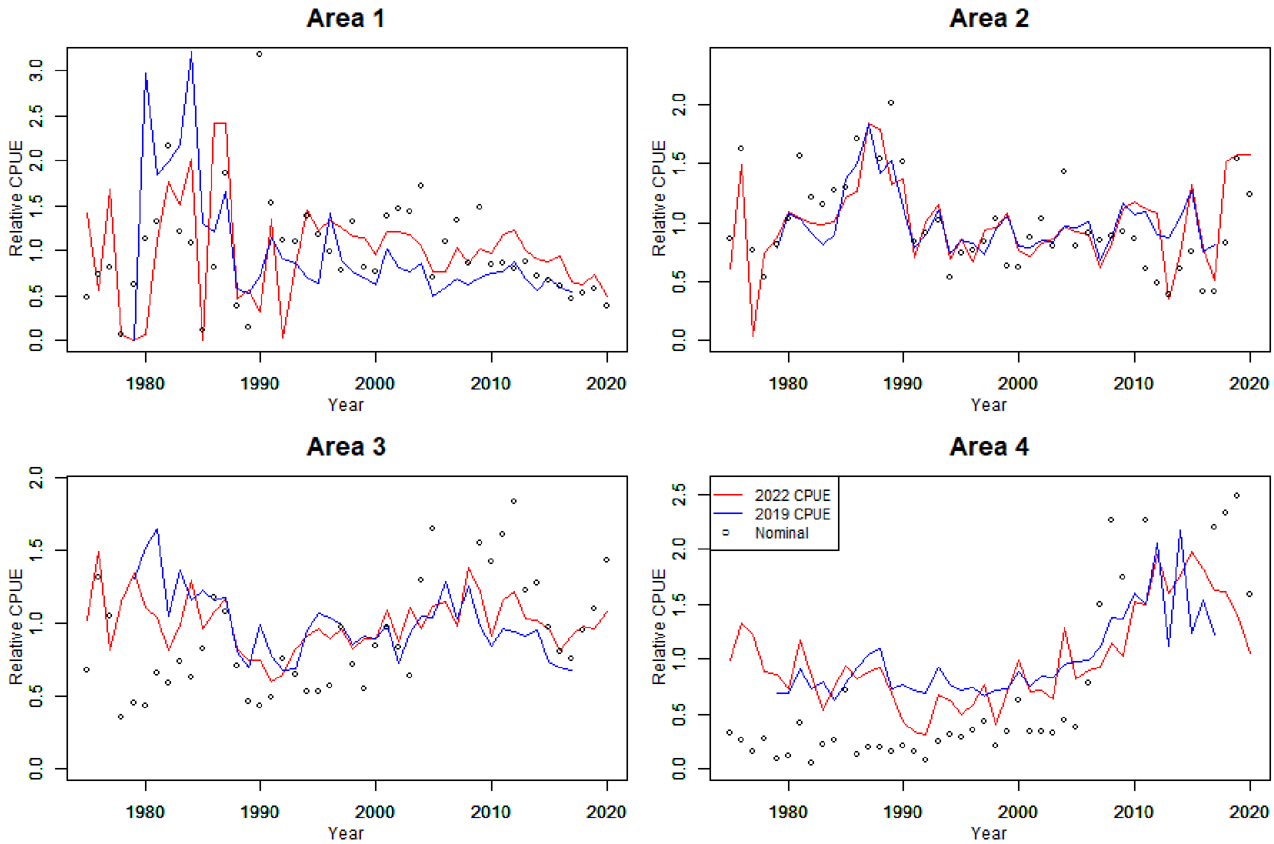


Fig. 6. Standardized year based CPUE in number for each area (CPUE2022) with comparison of nominal CPUE and CPUE in the previous study (CPUE2019: Matsumoto and Hoyle, 2019).

R1

R2

R3

R4

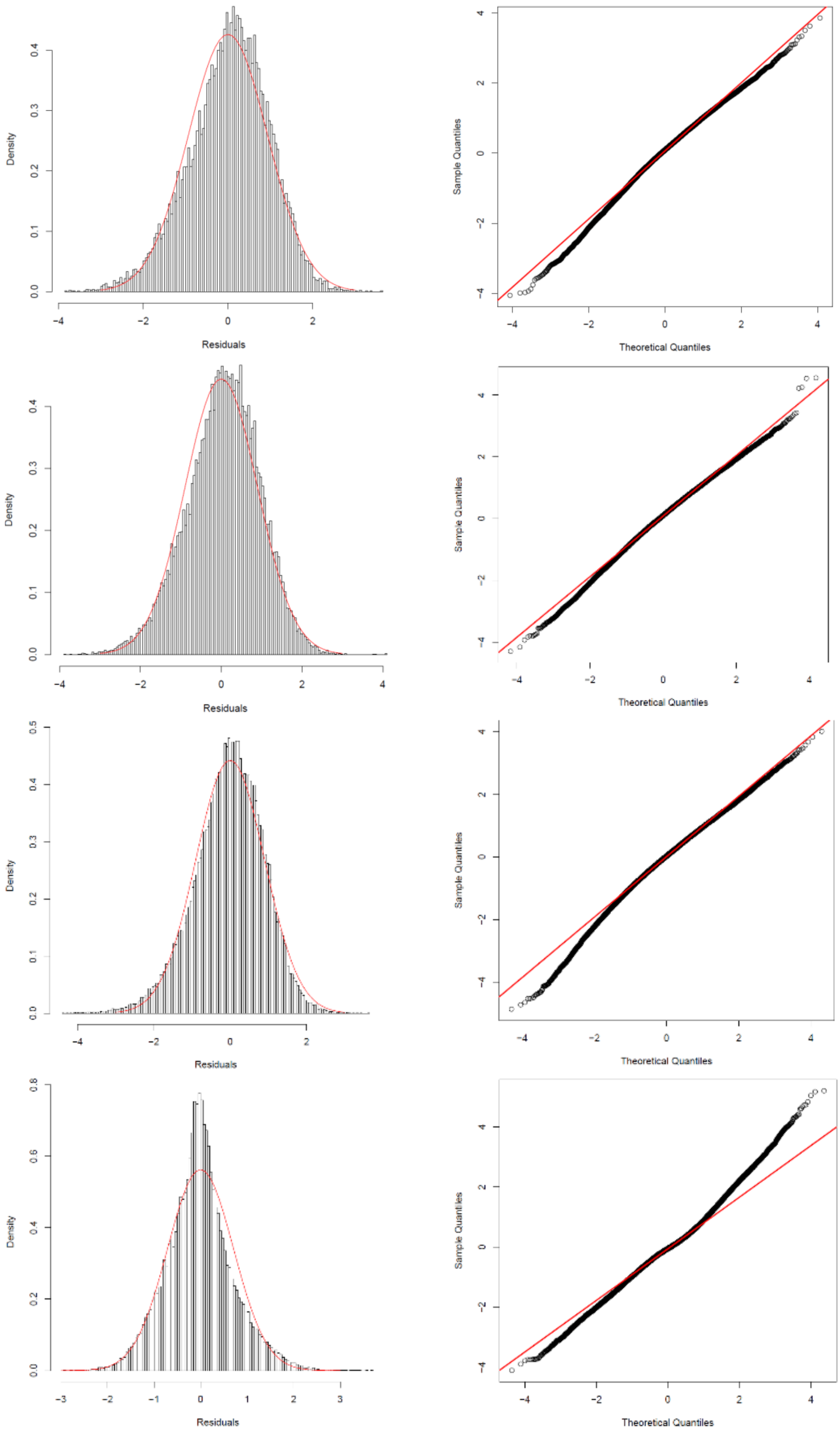


Fig. 7. Standardized residuals of year based CPUE standardization for each of four areas expressed as histograms and QQ plots.

R1

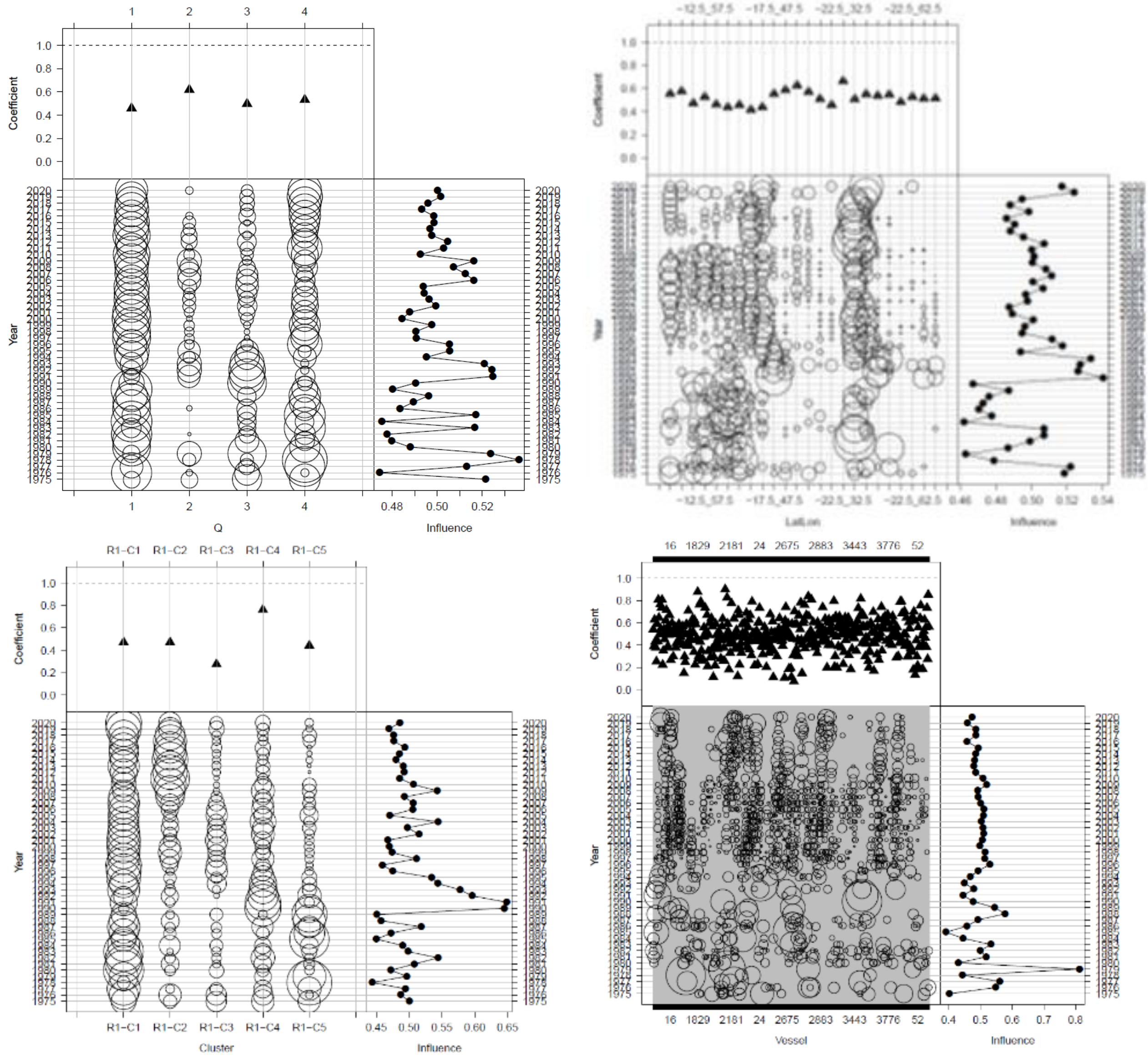


Fig. 8. Influence plot for CPUE standardization for albacore.

R2

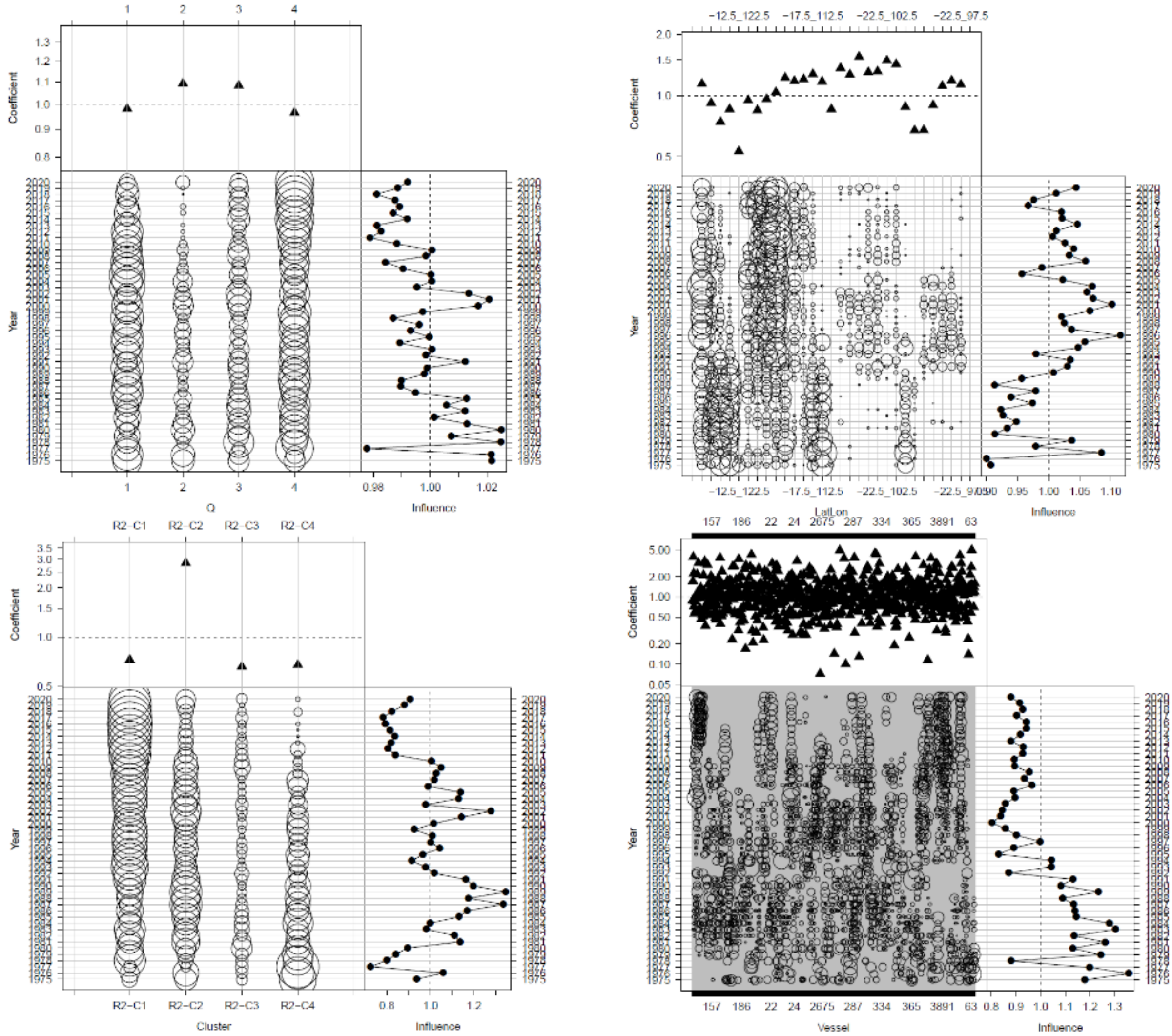


Fig. 8. Influence plot for CPUE standardization for albacore. **(continued)**

R3

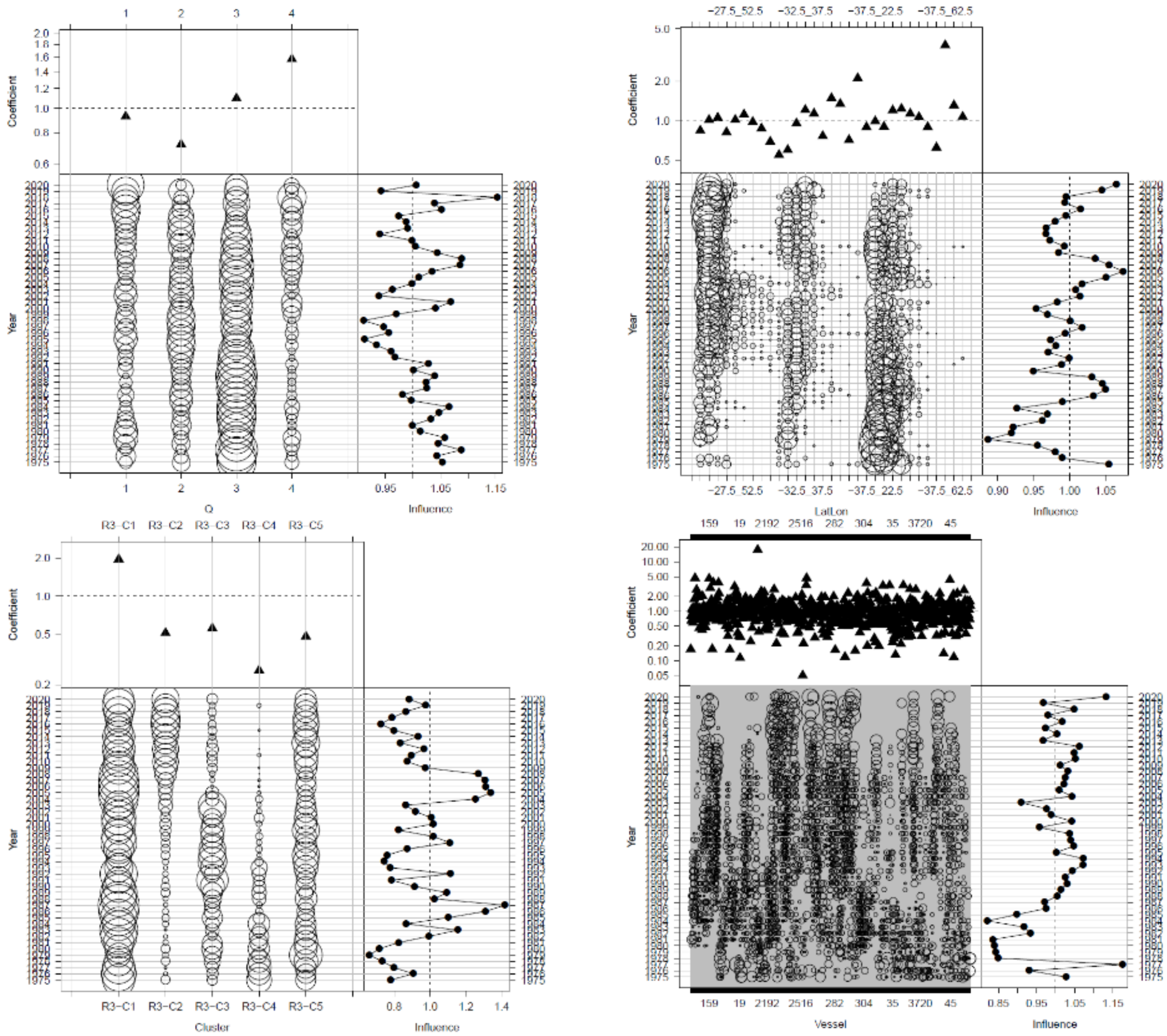


Fig. 8. Influence plot for CPUE standardization for albacore. **(continued)**

R4

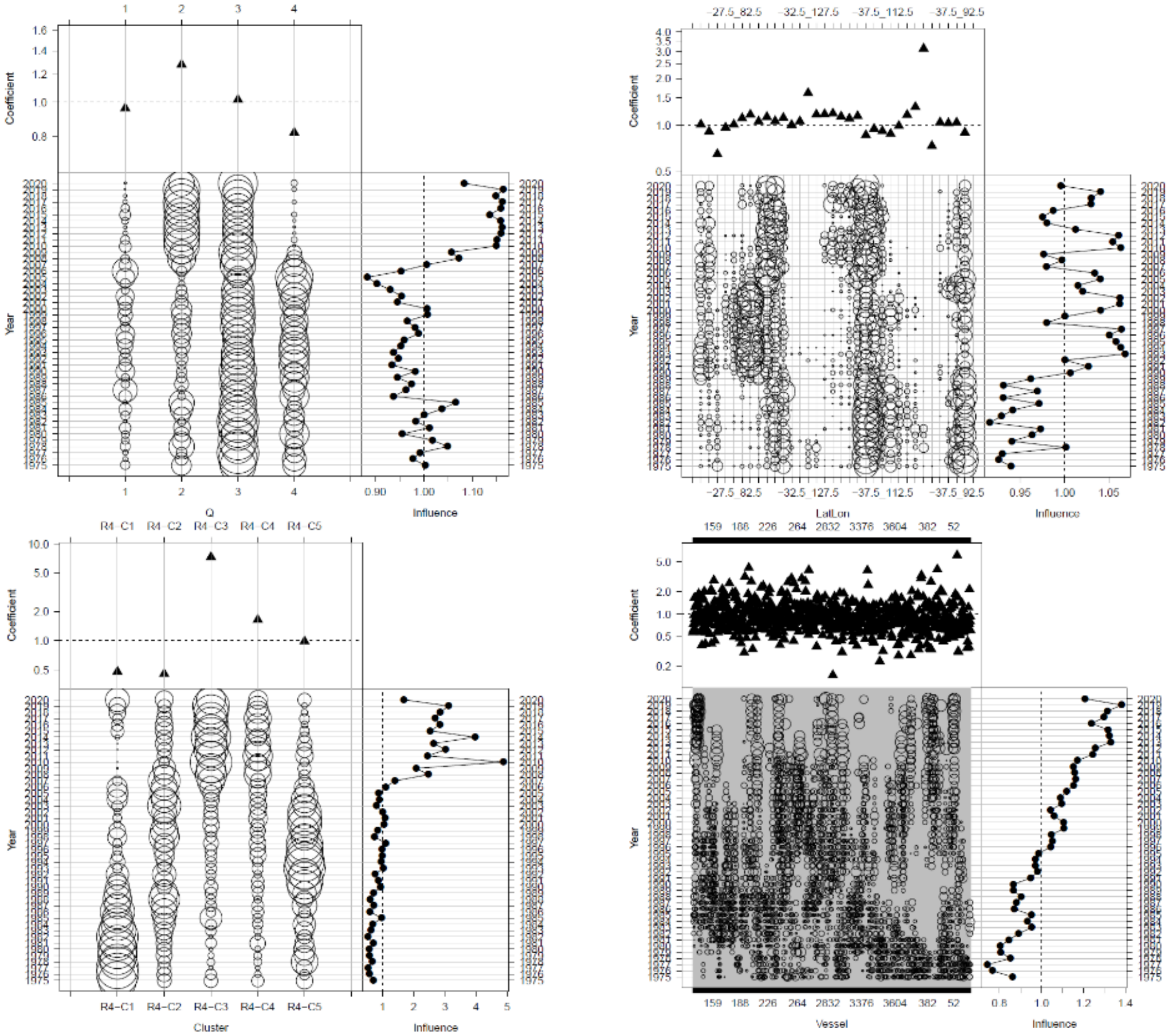


Fig. 8. Influence plot for CPUE standardization for albacore. **(continued)**