Japanese longline CPUE for yellowfin tuna in the Indian Ocean standardized by generalized linear model which includes cluster analysis

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Abstract

Japanese longline CPUE for yellowfin tuna in the Indian Ocean (area specific) was standardized for 1975-2023 by GLM based using the method in the new CPUE collaborative analysis. Japanese longline fishery logbook operational data was used for analyses. 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 blodks. Basically, standardized CPUEs showed similar trends among areas. CPUEs continuously decreased from 1970s to around mid 2010s, and those showed slight increasing grend after that. Trend of CPUEs was similar to those in the previous study.

1. Introduction

Yellowfin tuna is one of main target species for Japanese longline fishery in the Indian Ocean. Its abundance indices are very important for stock assessment or stock indicator of this species. Yellowfin tuna is mainly caught in the tropical and subtropical areas especially in the western Indian Ocean (Matsumoto and Satoh, 2012; Matsumoto 2014). Since 2007, piracy activities off Somalia has increased and spread to whole northwestern Indian Ocean. Japanese longline effort in the Indian Ocean, especially in the northwestern part, has rapidly decreased to avoid the piracy attack. In the IOTC WPTT meeting in 2010, a concern about the effect of the decreased effort on the CPUE trend of the longline fishery was recognized. Okamoto (2011b) estimated the regional effect of the decreased longline effort on the CPUE trend in the Indian Ocean, and suggested that the decreased effort in northwestern Indian Ocean has no more been able to represent the CPUE trend in this region. Therefore, Okamoto (2011a) calculated CPUE trends for both scenarios including and excluding Area 2 (northwestern area) and found that the trends were similar. At 2012-2015 IOTC WPTT meetings, Matsumoto et al. (2012, 2013) and Ochi et al. (2014, 2015) conducted CPUE standardization by using area rate without northwest area because no effort was observed in this area in 2011 due to piracy activities, and the indices were used for stock assessment in 2012 and 2015. Matsumoto et al. (2016) also reported standardization of yellowfin tuna CPUE based on similar methods as those in the previous studies with additionally using the effect of LT1LN1 (1 degree latitude/longitude effect). They found that there was only small difference of CPUE between with LT5LN5 and with LT1LN1. Matsumoto et al. (2016) also relieved tha concern that CPUE got higher as the number of hooks between floats (NHF) increases, which did not agree to expected result, by using LT5LN5 instead of subareas for the effect of fishing ground. Matsumoto (2017; 2018; 2019; 2020) reported similar results with updated data. In Matsumoto (2018), vessel effect was used for one of the effects (covariates) in the CPUE standardization using similar approach by Okamoto (2014), and found that it has some effect for CPUE trend.

In 2016, IOTC joint CPUE analysis (CPUE workshop) was conducted 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 were created (e.g. Matsumoto et al., 2018).

A new collaborative study for developing the abundance index started late 2019 by Japanese, Korean and Taiwanese scientists has been conducted for analyzing CPUE for Indian Ocean yellowfin tuna (Kitakado et al., 2021). In this collaborative study, in addition to the methods similar to those mentioned above, cutting-edge methods such as VAST (advanced spatio-temporal model) will also be developed.

This document reports the standardization of Japanese longline CPUE for yellowfin tuna in the Indian Ocean using the similar methods as those for joint CPUE (Japanese, Korean and Taiwanese longline fishery, conventional method) in the new collaborative study reported by Kitakado et al. (2021). The results may help to compare the results with those by new collaborative study (joint CPUE) and to compare CPUEs among fleets derived using the same or similar methods.

2. Materials and methods

The methods to standardize CPUE are similar to conventional regression analyses in the CPUE collaborative study mentioned above (Kitakado et al., 2021) except for data resolution for CPUE standardization.

Catch and effort data used:

Operational level (set by set) Japanese longline logbook data with vessel ID were used. The data were available for 1975-2023 (data for 2023 were 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**). Area 1 (northwest) was not used because there are not enough catch and effort. These regions are the same as those in the previous studies (e.g. Hoyle et al., 2018, Matsumoto et al., 2018), and also basically the same (except for northern and southern limits for region 1 and 3, respectively) as those for separating fleets or area for SS3 model in the previous stock assessment. Fig. 2 shows species composition of the catch by longline fishery in each area.

Cluster analysis

We clustered the data using the approach described by Kitakado et al. (2021), 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., 2018), 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 operational data. This data set was used for CPUE standardization.

GLM (generalized linear models) that assumed a lognormal distribution was conducted. In this approach the response variable log (CPUE+k) was used, and a normal distribution was assumed. The constant k, added to allow for modelling sets with zero catches of the species of interest, was 10% of the mean CPUE for all sets. CPUE was defined at the set level as catch in number divided by 1000 hooks. The following model was used:

$$\ln(CPUEs+k) \sim year+q+vessel+latlon5+\text{cluster}+ yr*q +\epsilon$$

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: 10% of the mean CPUE

All the covariates were incorporated as fixed effect. As for diagnostics of CPUE standardization, residual distributions, Q-Q plots and influence plots were produced.

3. Results 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 yellowfin tuna was dominant. Number of clusters were 4 or 5 for each region.

ANOVA indicates that as for all the regions all the effects were effective at 1% significance level (Table **1**). Fig. 5 shows comparison of yellowfin CPUE by area, and Fig. 6 shows comparison of yellowfin CPUE in each area with nominal CPUE and standardized CPUE in the previous study (Matsumoto et al. 2021). The trend of CPUE is similar among areas with some difference in recent years. CPUEs continuously decreased from 1970s to around mid 2010s, and those showed slight increasing grend after that especially in R2 and R3. Very high jump of CPUE in 2020 was observed in R2, which may be due to samall number of operations (**Error! Reference source not found.**). The trend of CPUE in this study is similar to those in the previous study (Matsumoto et al., 2021), and there are some small scale differences.

Fig. 7 shows distribution of standardized residuals and QQ plots. It seems that the distributions are not largely skewed except for R3. **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, $latlon5$ effect is increasing in region 2 and 4, although there is no clear trend in region 3.

4. References

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Table 1. ANOVA table of GLM for year based area specific CPUE standardization.

R1

```
        LR Chisq  Df Pr(>Chisq)
Year        5008  47  < 2.2e-16 ***
Q           1201   3  < 2.2e-16 ***
LatLon      3155  39  < 2.2e-16 ***
Cluster    88619   4  < 2.2e-16 ***
Vessel     14513 699  < 2.2e-16 ***
Year:Q      5096 118  < 2.2e-16 ***
```

R2

```
        LR Chisq  Df Pr(>Chisq)
Year        5527  48  < 2.2e-16 ***
Q            468   3  < 2.2e-16 ***
LatLon     21628  28  < 2.2e-16 ***
Cluster   141551   4  < 2.2e-16 ***
Vessel     30891 821  < 2.2e-16 ***
Year:Q     10189 143  < 2.2e-16 ***
```

R3

```
        LR Chisq  Df Pr(>Chisq)
Year        6731  48  < 2.2e-16 ***
Q           1725   3  < 2.2e-16 ***
LatLon     37484  66  < 2.2e-16 ***
Cluster    64051   4  < 2.2e-16 ***
Vessel     39386 975  < 2.2e-16 ***
Year:Q      7134 143  < 2.2e-16 ***
```

R4

```
        LR Chisq  Df Pr(>Chisq)
Year        5917  48  < 2.2e-16 ***
Q           1204   3  < 2.2e-16 ***
LatLon      2451  32  < 2.2e-16 ***
Cluster    35678   3  < 2.2e-16 ***
Vessel     19806 819  < 2.2e-16 ***
Year:Q      4250 142  < 2.2e-16 ***
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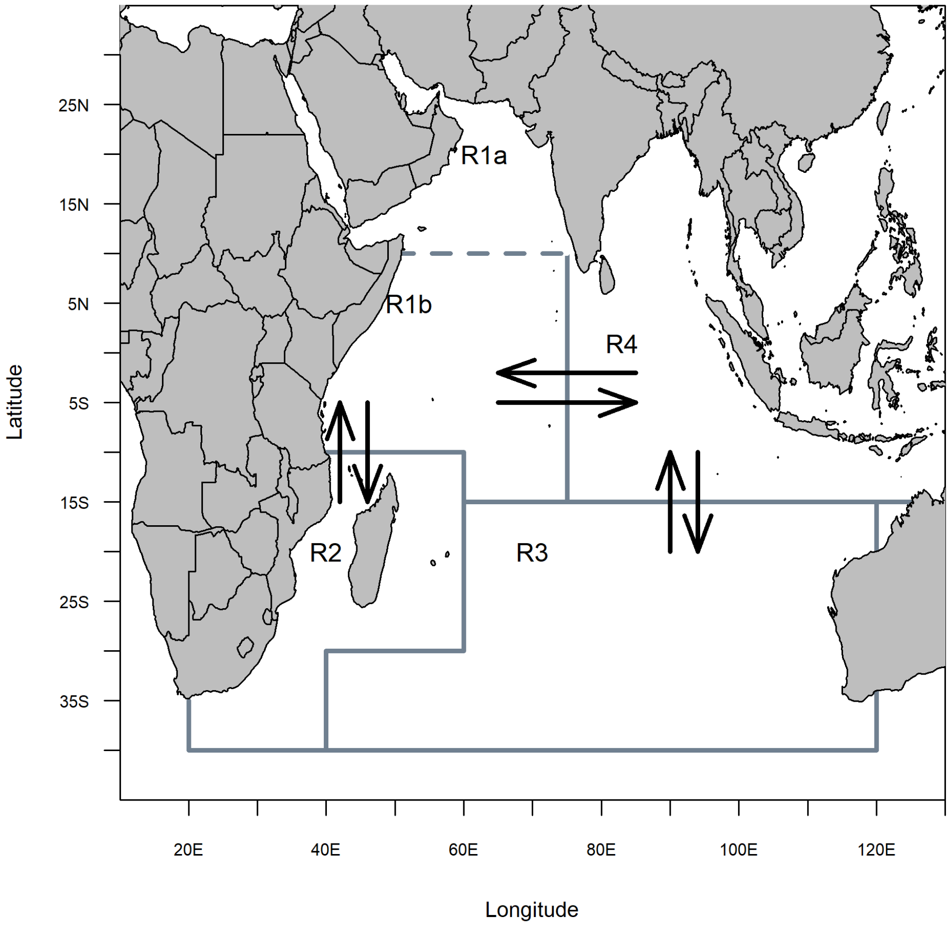


Fig. 1. Definition of areas used in this study. R1a and R1b were combined as R1.

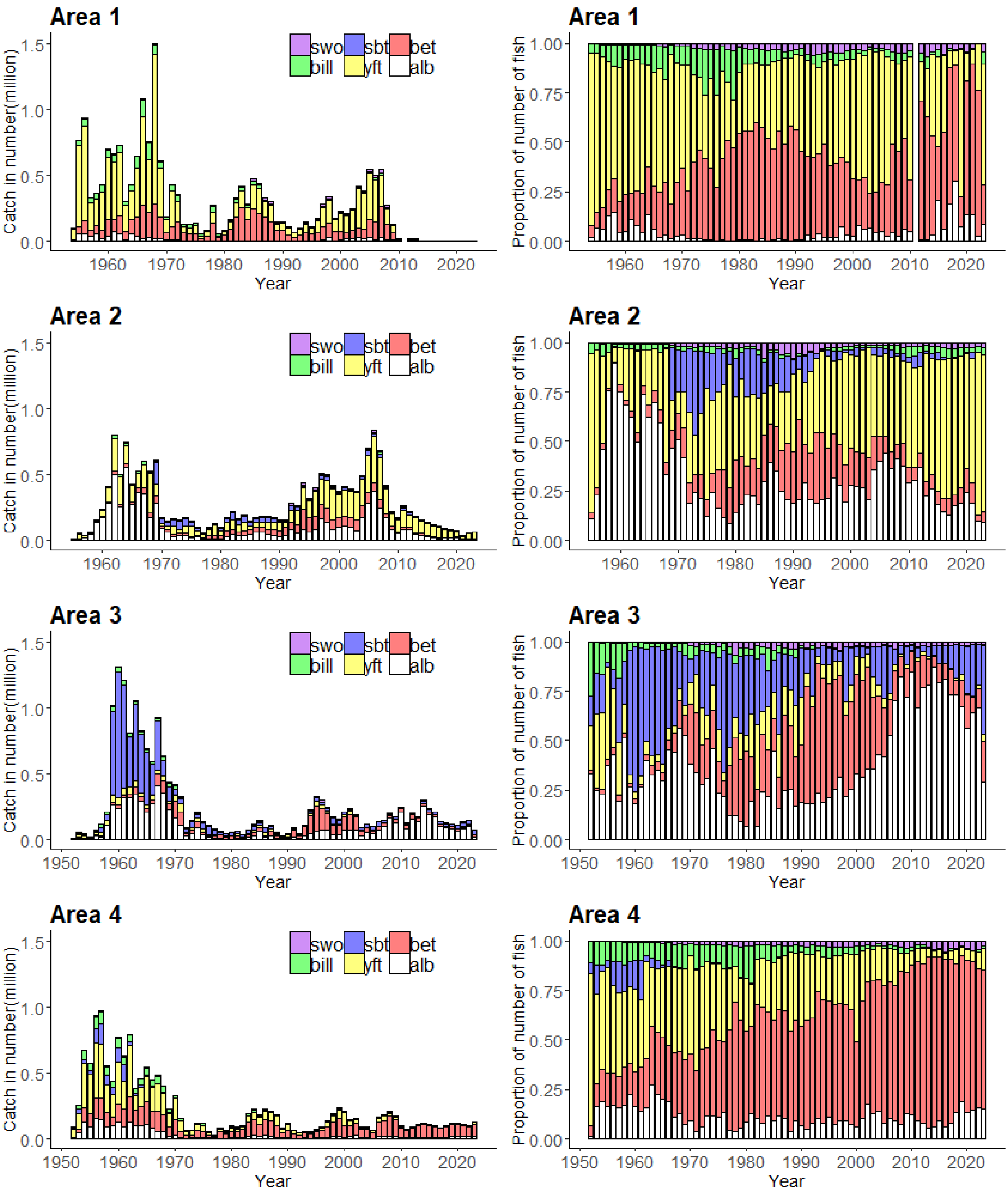
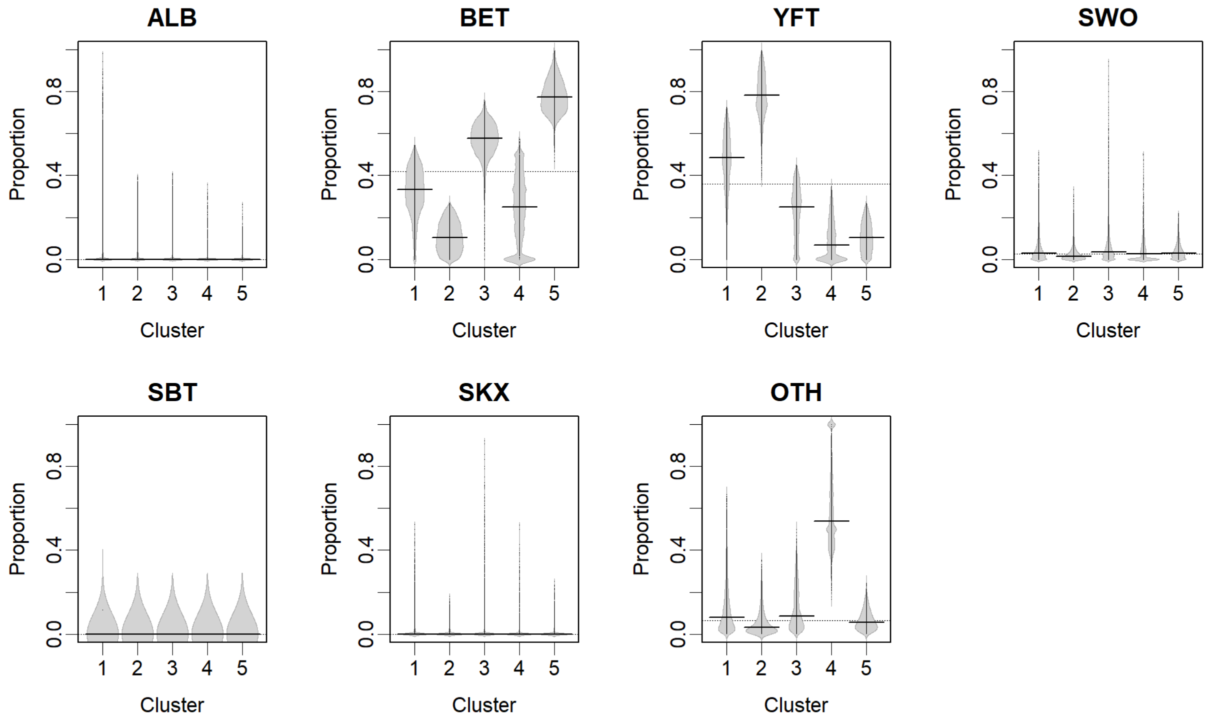


Fig. 2. Species composition of catch in number in the Indian Ocean by the Japanese longline fishery in each area shown in Fig. **1**.

R1



R2

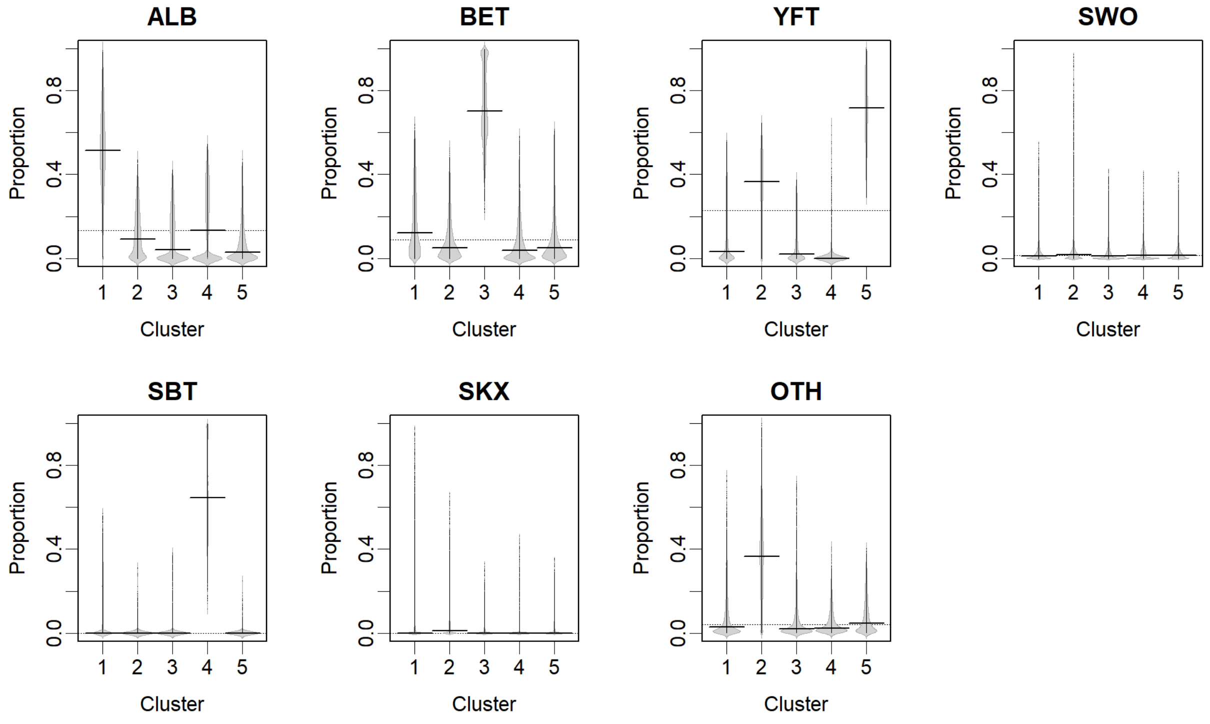
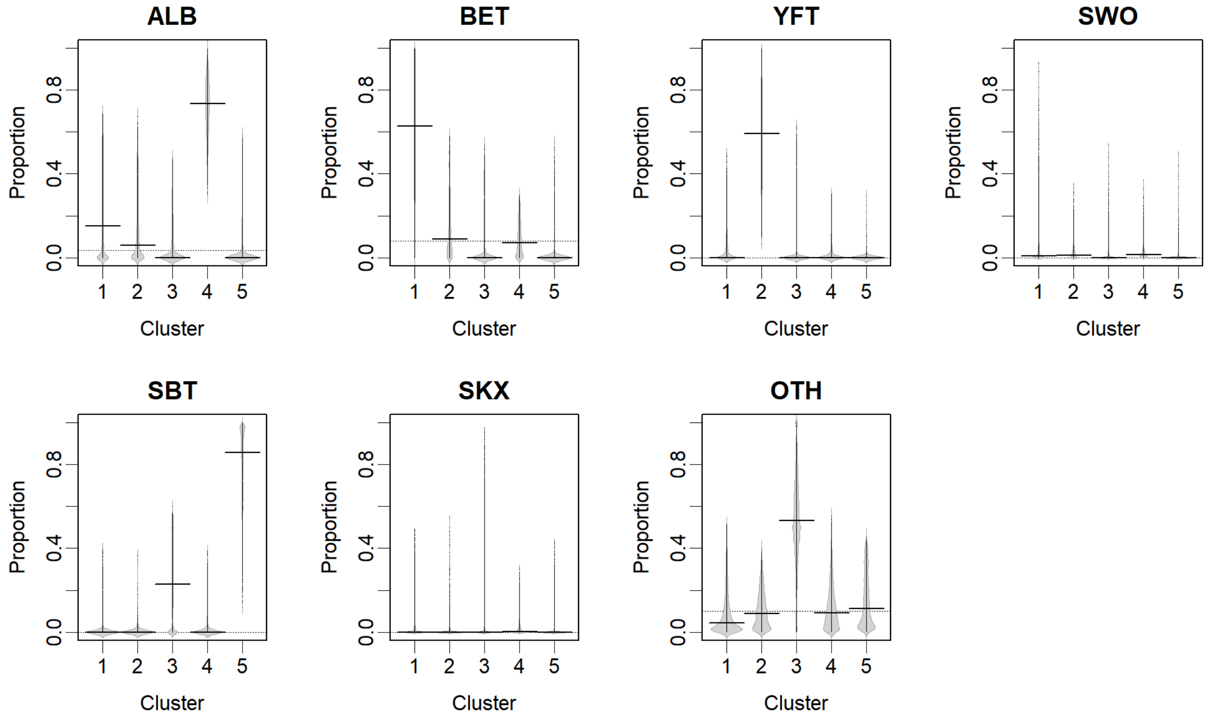


Fig. 3. Beanplots for yellowfin region showing species composition by cluster for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH). The horizontal bars indicate the medians.

R3



R4

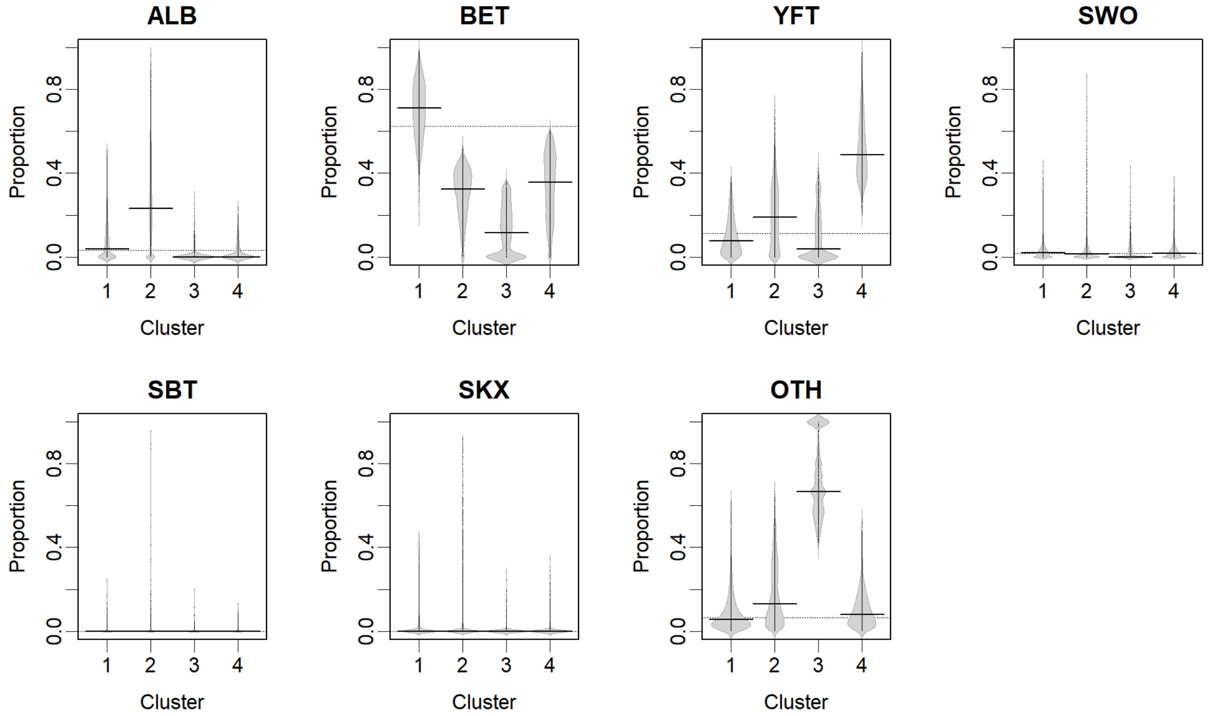


Fig. 3. Beanplots for yellowfin region showing species composition by cluster for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH). The horizontal bars indicate the medians. (continued)

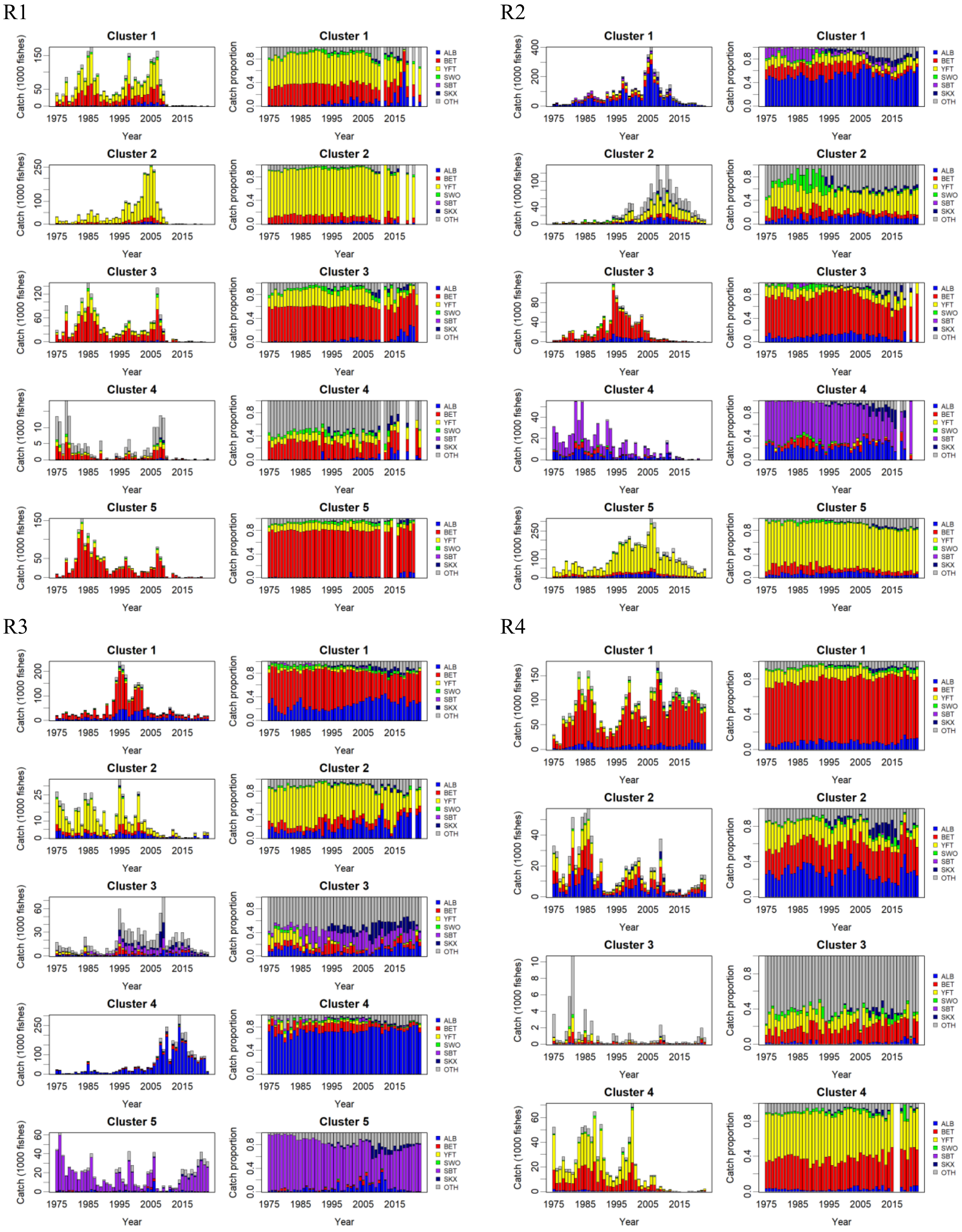


Fig. 4. Annual change in species composition for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), bluefin tuna (BFT), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH) by cluster and area.

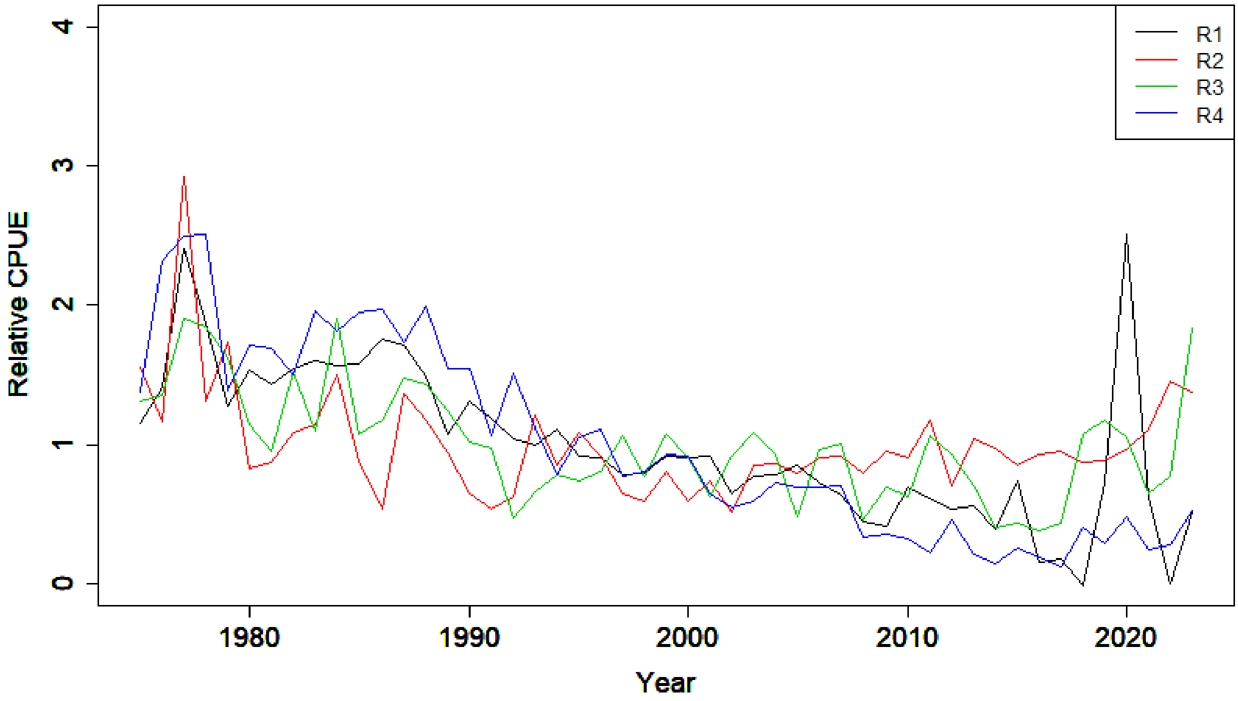


Fig. 5. Standardized year based CPUE in number for each area.

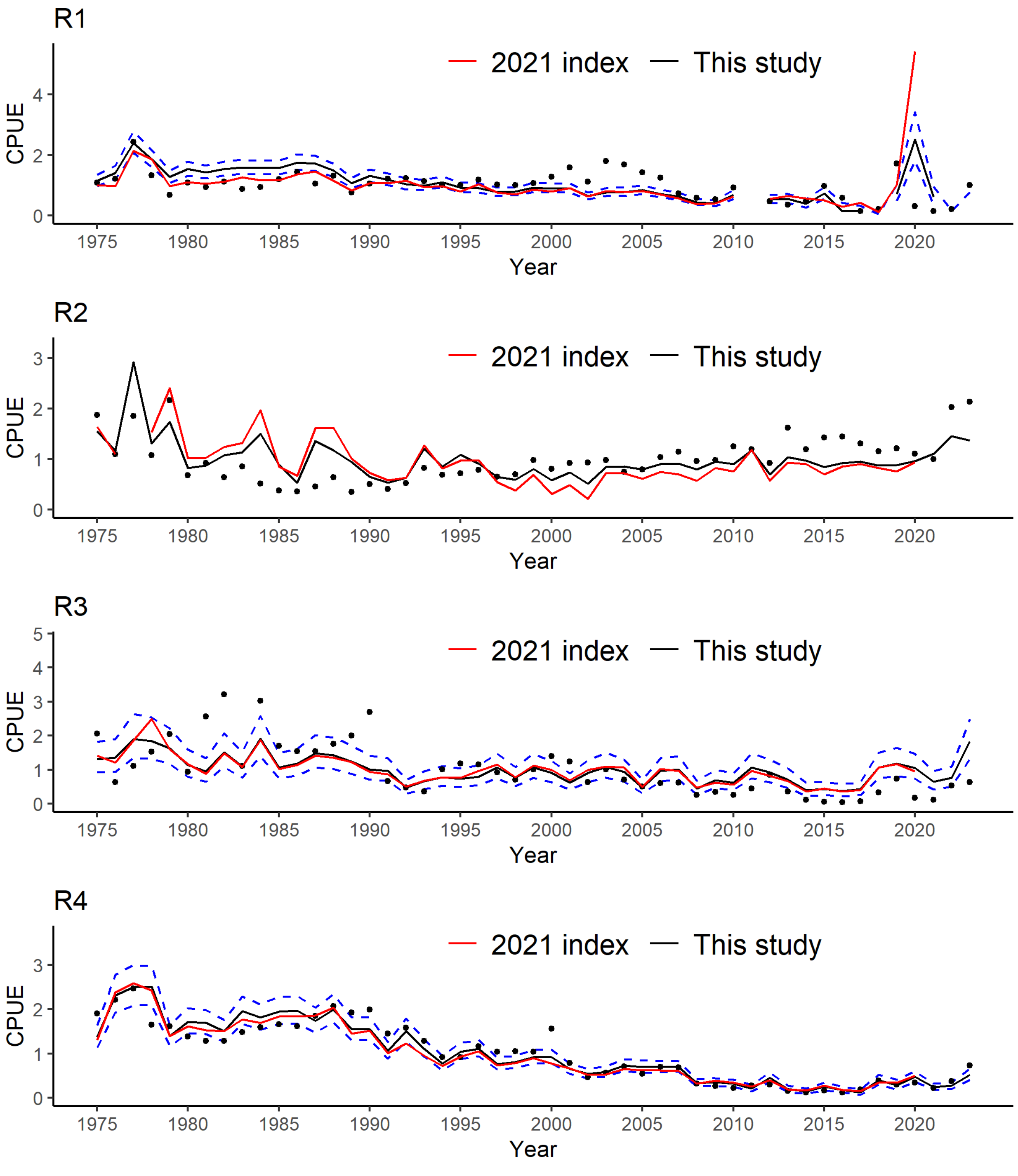


Fig. 6. Standardized year based CPUE in number for each area with comparison of nominal CPUE (dots) and CPUE in the previous study (Matsumoto et al., 2021). Dashed lines and dots show 95% confidence interval. Note: confidence interval for R2 is out of range of the graph.

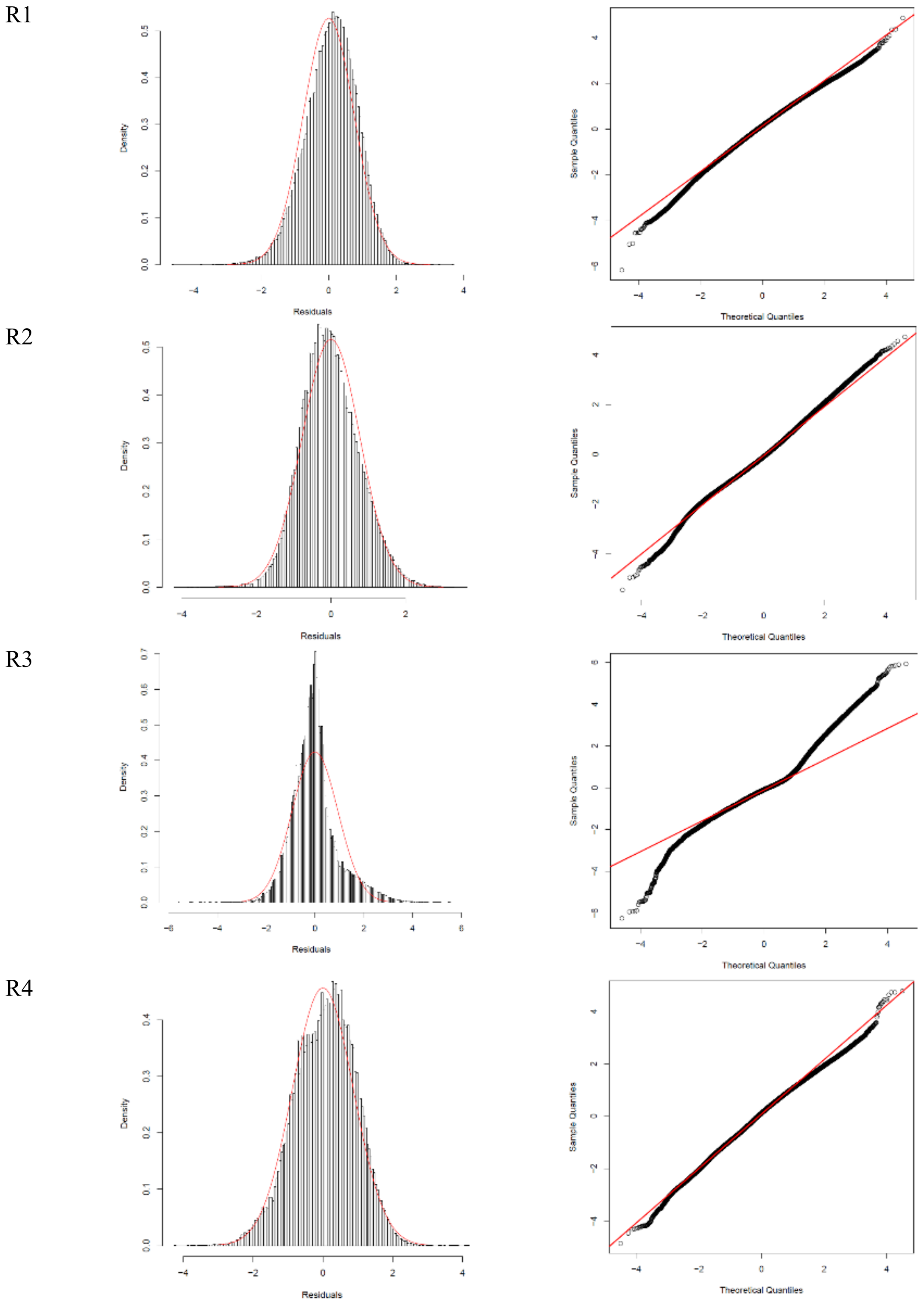


Fig. 7. Standardized residuals of year based CPUE standardization for each of four areas expressed as histograms and QQ plots.

R1

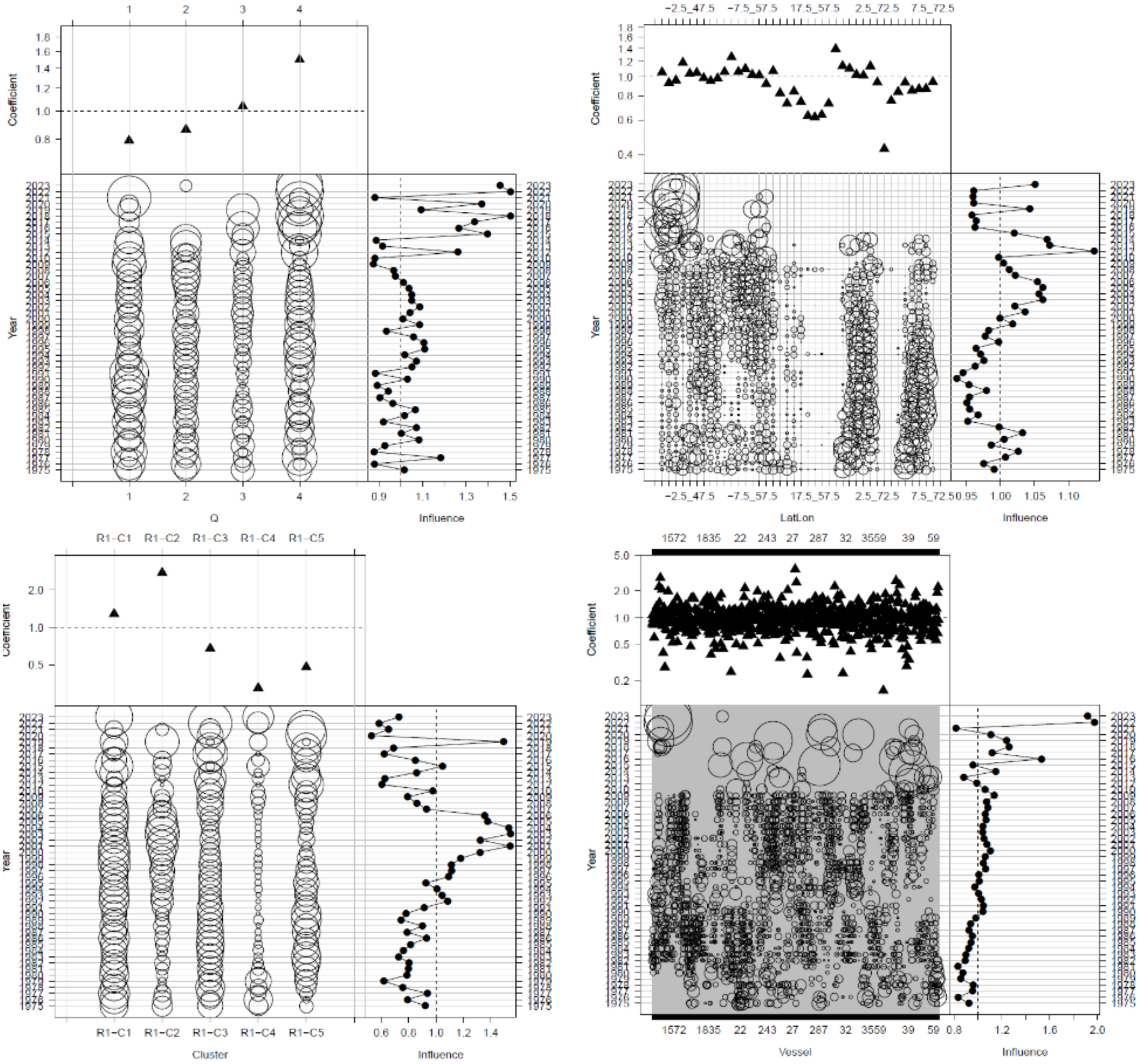


Fig. 8. Influence plot for CPUE standardization for yellowfin.

R2

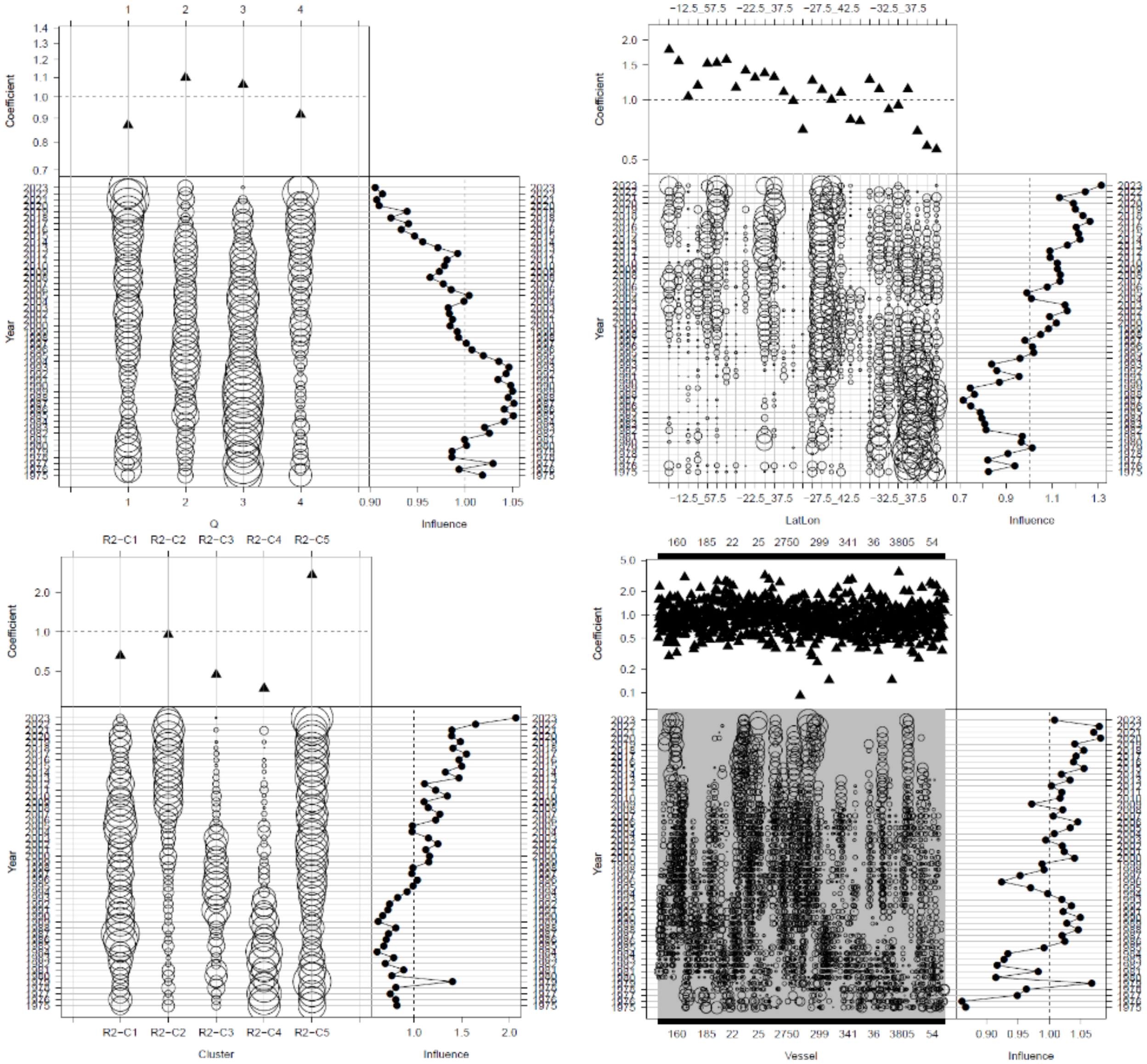


Fig. 8. Influence plot for CPUE standardization for yellowfin. **(continued)**

R3

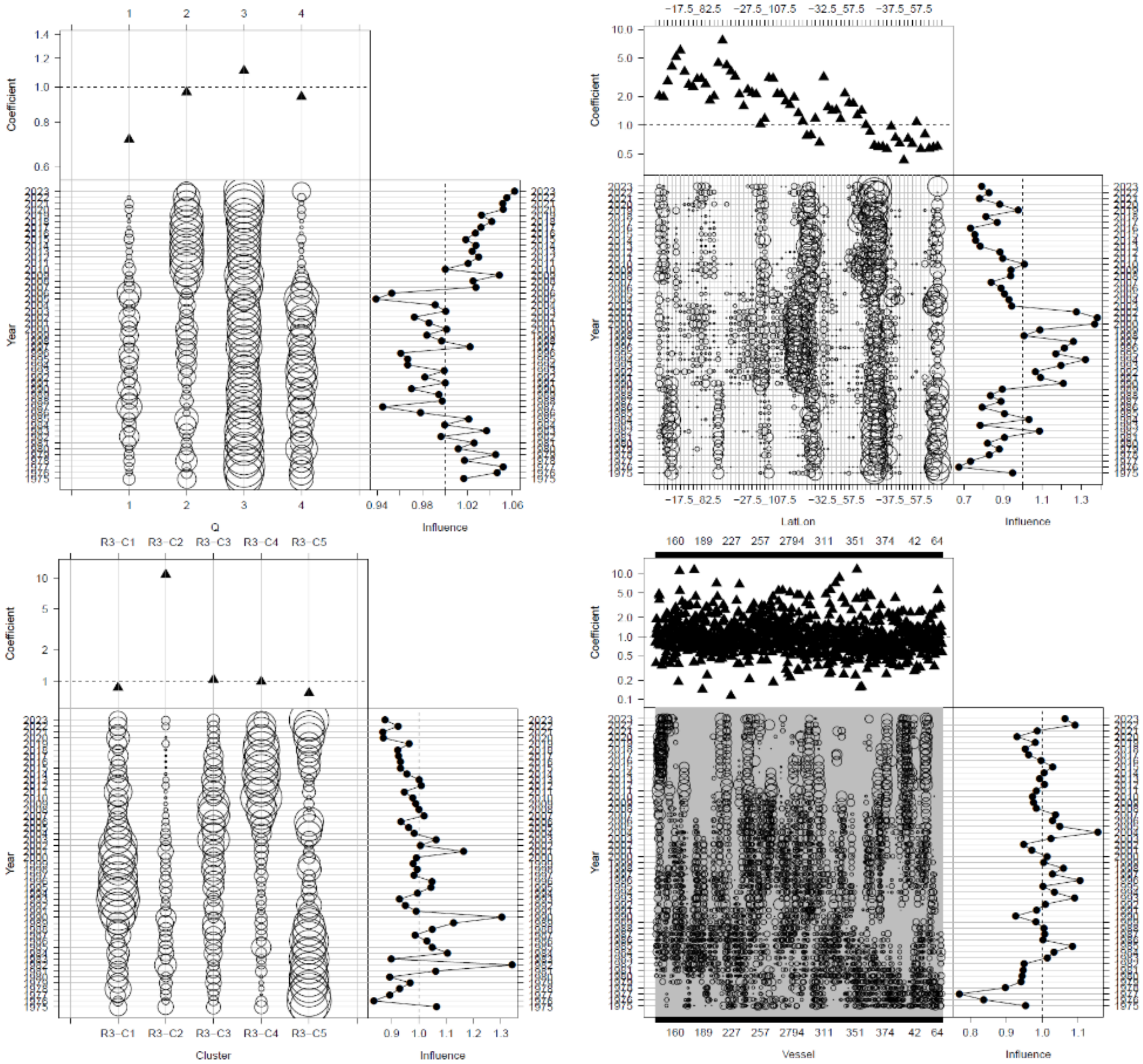


Fig. 8. Influence plot for CPUE standardization for yellowfin. **(continued)**

R4

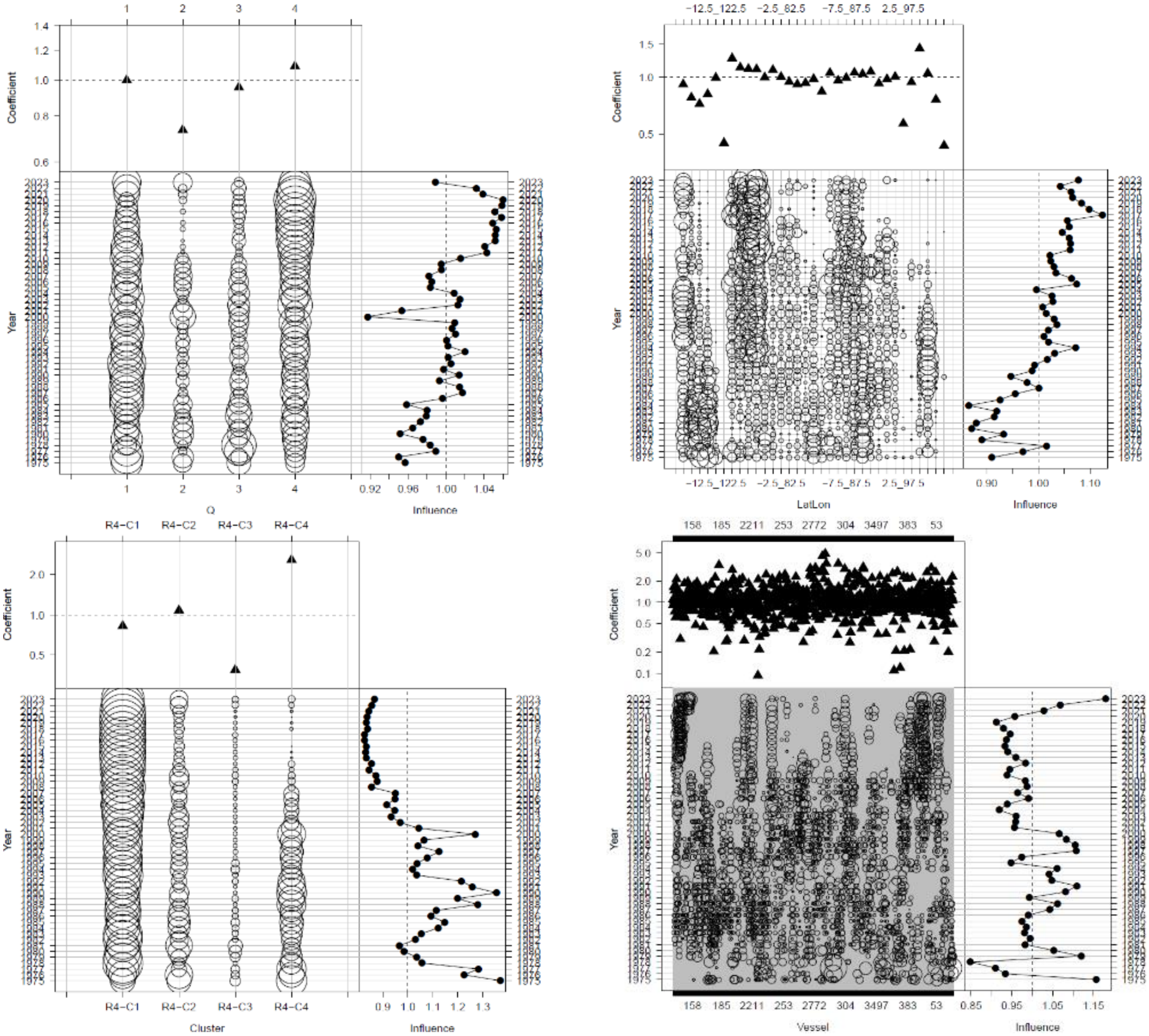


Fig. 8. Influence plot for CPUE standardization for yellowfin. **(continued)**