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STANDARDIZATION OF YELLOWFIN TUNA CPUE IN THE ATLANTIC OCEAN BY THE JAPANESE LONGLINE FISHERY

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SUMMARY

Standardization of yellowfin tuna CPUE by Japanese longline in the Atlantic Ocean was conducted using generalized linear models (GLM) with log normal errors. The models incorporated fishing power based on vessel ID and used cluster analysis to account for targeting. The variables year, quarter, vessel ID, latlon5 (five-degree latitude-longitude block), cluster, and year-quarter interaction were used in the standardization. The number of clusters was 4 or 5 per region. Dominant species differed among clusters. The trend of CPUE was similar between region 2 (central) and 3 (south). with some differences. The CPUE trends were similar to those in the previous study.

RÉSUMÉ

La standardisation de la CPUE de l'albacore provenant des palangriers japonais opérant dans l'océan Atlantique a été réalisée au moyen de modèles linéaires généralisés (GLM) avec des erreurs log-normales. Les modèles intègrent la puissance de pêche basée sur l'identification du navire et utilisent l'analyse de grappes pour tenir compte du ciblage. Les variables année, trimestre, ID du navire, lat-lon5 (bloc de cinq degrés de latitude-longitude), grappe et interaction année-trimestre ont été utilisées dans la standardisation. Le nombre de grappes était de 4 ou 5 par région. Les espèces dominantes différaient d'une grappe à l'autre. La tendance de la CPUE était similaire entre les régions 2 (centrale) et 3 (sud), avec quelques différences. Les tendances de la CPUE étaient similaires à celles de l'étude précédente.

RESUMEN

Se estandarizó la CPUE de patudo de la pesquería de palangre japonesa en el océano Atlántico mediante modelos lineales generalizados (GLM) con errores lognormales. Los modelos incorporaban la potencia pesquera basándose en la ID del buque y utilizaron un análisis de conglomerado para tener en cuenta la estrategia de pesca en función de la especie objetivo. En la estandarización se utilizaron las variables año, trimestre, ID del buque, latlon5 (bloques de cinco grados de latitud-longitud), conglomerado e interacción año-trimestre. El número de conglomerados fue de 4 o 5 por región. Las especies predominantes diferían en los diferentes conglomerados. La tendencia de la CPUE era similar entre la región 2 (central) y la región tres (sur) con algunas diferencias. Las tendencias de la CPUE eran similares a las del estudio previo.

KEYWORDS

Atlantic, Yellowfin, Longline, Catch/effort

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1. Introduction

Longline is the only tuna-fishing gear deployed by Japan at present in the Atlantic Ocean, and yellowfin tuna is one of the main components of the catch (Anonymous, 2013). Japanese fishing effort covers a wide area of the Atlantic Ocean, and yellowfin tuna is mainly caught in tropical areas. Standardized CPUE for yellowfin tuna caught by the Japanese fleet, along with other CPUE indices, has long been used as input data in stock assessment models for Atlantic Ocean yellowfin tuna.

To date, national scientists have standardized Japanese longline CPUE for yellowfin tuna in the Atlantic using generalized linear models (GLM) mainly with lognormal errors, and with either operational or aggregated catch and effort data based on logbooks (e.g., Okamoto and Satoh, 2009, Satoh et al., 2012; Matsumoto and Satoh, 2015). The standardizations have incorporated the effects of fishing season, area, fishing gear (number of hooks between floats and gear material) and an environmental factor (sea surface temperature). These may be termed 'simple' and 'traditional' methods.

In recent years, collaborative analyses of CPUE for tuna species in the Indian Ocean have been conducted, with 'joint CPUEs' (CPUE based on multiple longline fleets) as well as CPUE for each fleet created for albacore, bigeye and yellowfin tuna, based on logbook operational data from several longline fleets (e.g. Hoyle et al., 2016; 2017). In April 2018 ICCAT held a bigeye CPUE collaborative analysis workshop to create CPUE indices for bigeye tuna in the Atlantic Ocean using the same approaches used for Indian Ocean stocks (Hoyle et al., 2018). These analyses involve consideration of fishing power (vessel effect) based on vessel IDs and cluster analysis based on species composition of the catch to incorporate species targeting. Bigeye and/or yellowfin tuna CPUE indices for the Japanese longline fleet in the Indian Ocean have also been prepared using the same methods as those for joint CPUE (Matsumoto et al., 2017, Matsumoto et al., 2018). In April 2019 ICCAT held a yellowfin CPUE collaborative analysis workshop to create CPUE indices for yellowfin tuna in the Atlantic Ocean, and joint (Hoyle et al., 2019) and Japanese (Matsumoto et al., 2019) longline CPUE for yellowfin were created.

A new collaborative study for developing the abundance index started in 2019 by Japanese, Korean and Taiwanese scientists has been conducted (Kitakado et al., 2021). In this collaborative study, some changes of methodology for clustering have been made from the previous collaborative study. Matsumoto et al. (2021) reported standardization of bigeye tuna CPUE by Japanese longline fishery based on the new collaborative study.

ICCAT SCRS meeting in 2022 recommended to update CPUE for tropical tuna species during 2023 (ICCAT, 2022). This study was conducted based on this recommendation.

This document reports standardized CPUE for yellowfin tuna by Japanese longline fishery in the Atlantic Ocean using the methods in the new collaborative study reported by Kitakado et al. (2021). The results may help to see the indicator of the stock.

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, Matsumoto et al., 2021).

2.1 Catch and effort data used

Operational level (set by set) Japanese longline logbook data with vessel ID were used. The data were available for 1975-2021 (data for 2021 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 a yellowfin region (subarea) (**Figure 1**). These regions are the same as those in the previous studies (e.g. Hoyle et al., 2019, Matsumoto et al., 2019), 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 (2019) stock assessment.

2.2 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 bluefin tuna (BFT), 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.

2.3 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:

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

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.

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

Species compositions were plotted by cluster for each region (**Figure 2**) and each region and year (**Figure 3**), as were the relative distributions of covariates (**Figure 4**). Dominant species differed depending on clusters, but there was 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**). Custer effect was largest in regions 1 and 3, and laoton5 effect was largest in region 2. **Figure 5** shows the trend of standardized CPUE for yellowfin in each region. The trend was similar between region 1 and 2 with some differences especially for recent periods. In these regions, CPUE shows slight increase until around 1980, was decreasing trend until around 2010 and is slight increasing trend after that in regions 2. CPUE shows overall increasing trend with fluctuation in region 3. **Figure 6** shows comparison of yellowfin CPUE with those in the previous study by the previous collaborative analysis (Matsumoto et al. 2019). The trend of CPUE in this study is similar to that in the previous study, and there are some small scale differences especially in region 1.

Figure 7 shows distribution of standardized residuals and QQ plots. It seems that the distribution is not largely skewed, but some skew is seen for region 1. **Figure 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.

4. Discussion

This study is considered to be useful for providing the indicator of the stock based on Japanese longline fishery, and for comparing the trend of CPUE with that for other fleet. Although joint CPUE seems better for input data in the stock assessment models, each fleet CPUE is still necessary to be provided for the purpose of comparison and so on. Seeing the trend of CPUE in region 2 (main fishing area for tropical tuna), it is slightly increasing in recent years, suggesting that the stock is possibly recovering.

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Table 1. Results of ANOVA table of CPUE standardization for each of three areas divided from all Atlantic area definition.

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R1
Analysis of Deviance Table (Type II tests)

Response: log(CPUE + const)
        LR Chisq  Df Pr(>Chisq)
Year        2398  46  < 2.2e-16 ***
Q            920   3  < 2.2e-16 ***
LatLon     18868  63  < 2.2e-16 ***
Cluster    33110   4  < 2.2e-16 ***
Vessel      9726 589  < 2.2e-16 ***
Year:Q      4738 120  < 2.2e-16 ***
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R2
Analysis of Deviance Table (Type II tests)

Response: log(CPUE + const)
        LR Chisq  Df Pr(>Chisq)
Year      1629.1  46  < 2.2e-16 ***
Q          158.6   3  < 2.2e-16 ***
LatLon   15897.1  54  < 2.2e-16 ***
Cluster   6674.2   4  < 2.2e-16 ***
Vessel    9221.9 796  < 2.2e-16 ***
Year:Q    2229.5 138  < 2.2e-16 ***
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R3
Analysis of Deviance Table (Type II tests)

Response: log(CPUE + const)
        LR Chisq  Df Pr(>Chisq)
Year      1904.3  46  < 2.2e-16 ***
Q          104.8   3  < 2.2e-16 ***
LatLon    7346.3  19  < 2.2e-16 ***
Cluster  11948.6   3  < 2.2e-16 ***
Vessel    7808.0 752  < 2.2e-16 ***
Year:Q    3029.5 137  < 2.2e-16 ***
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Significance level:  0  ‘***’  0.001  ‘**’  0.01  ‘*’  0.05  ‘.’  0.1  ‘ ’  1
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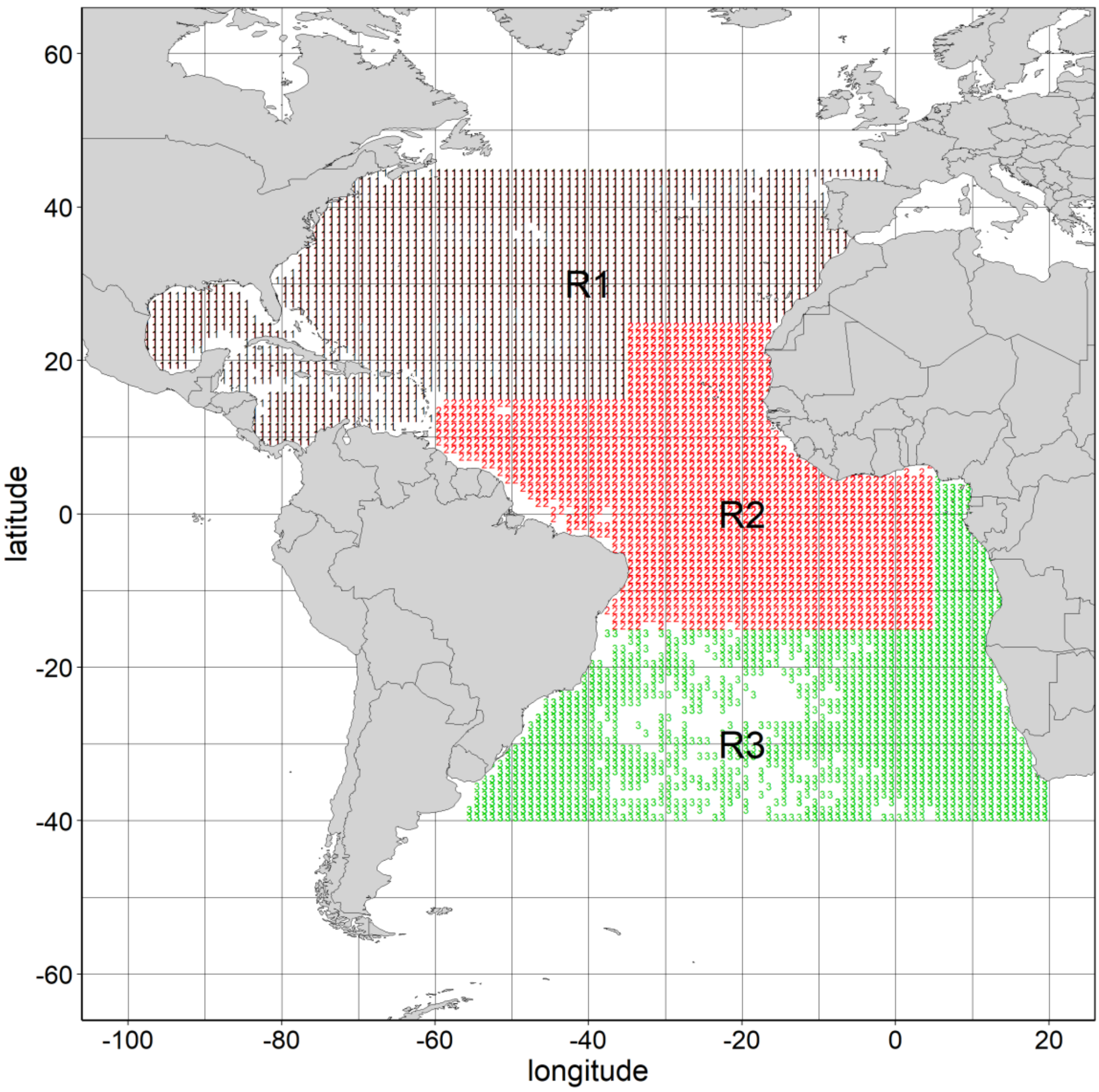
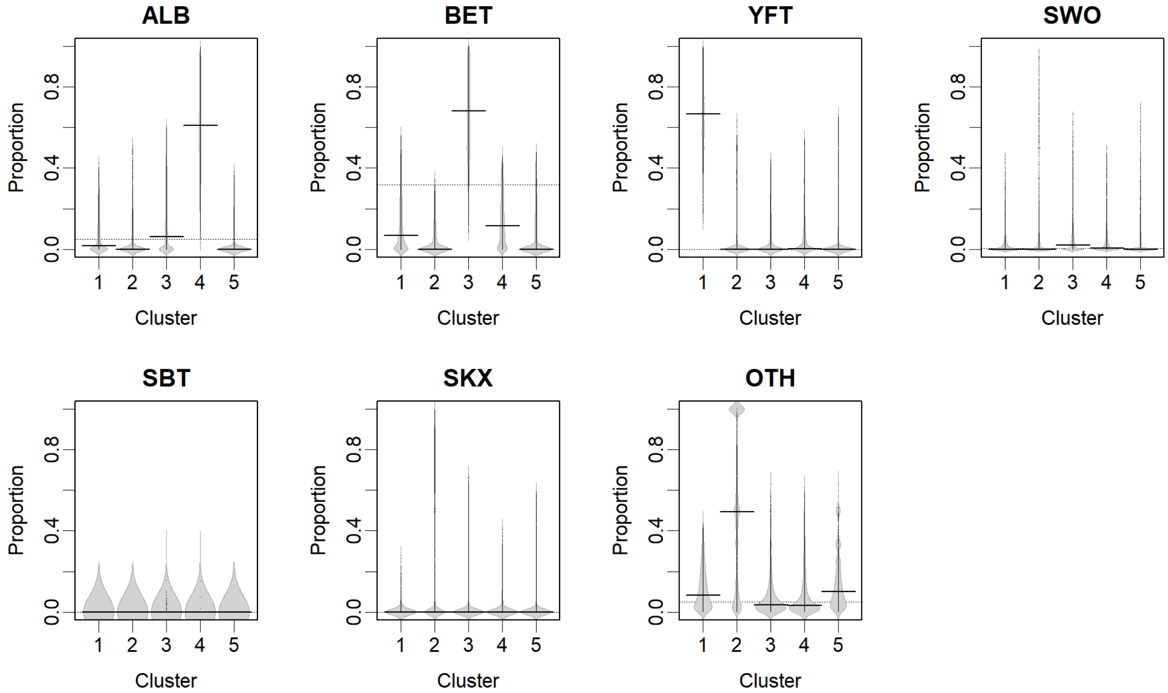


Figure 1. Map of the regional structures used to estimate yellowfin CPUE indices.

R1



R2

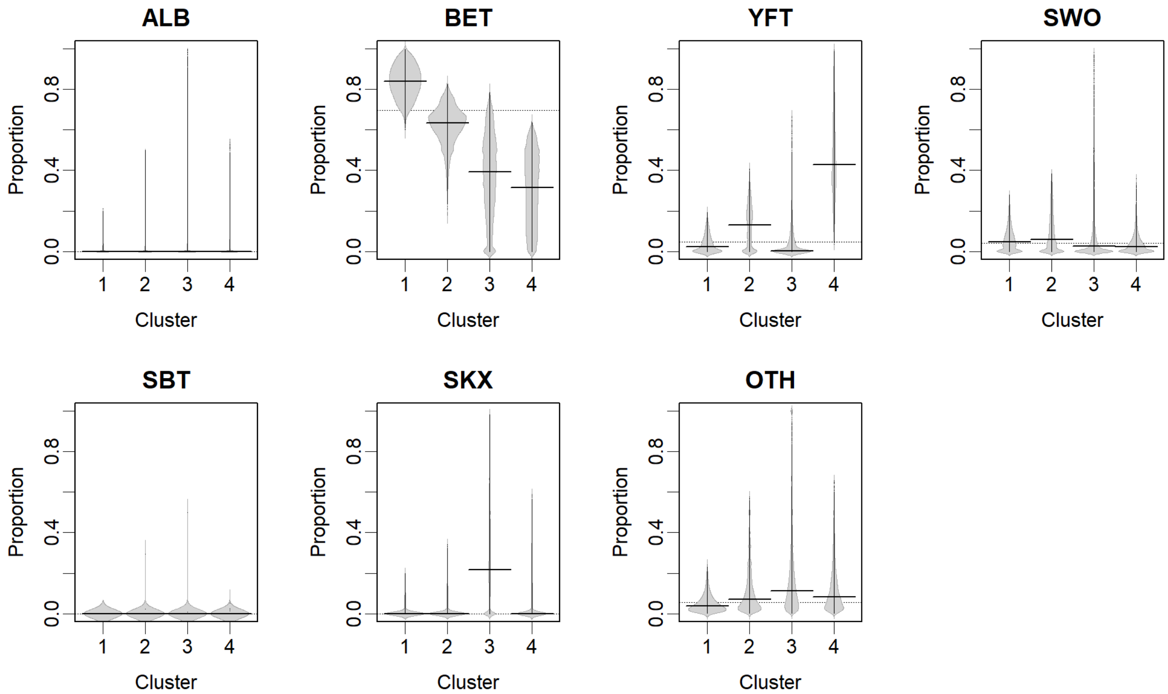


Figure 2. Beanplots for yellowfin region showing species composition by cluster for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), bluefin tuna (BFT), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH). The horizontal bars indicate the medians.

R3

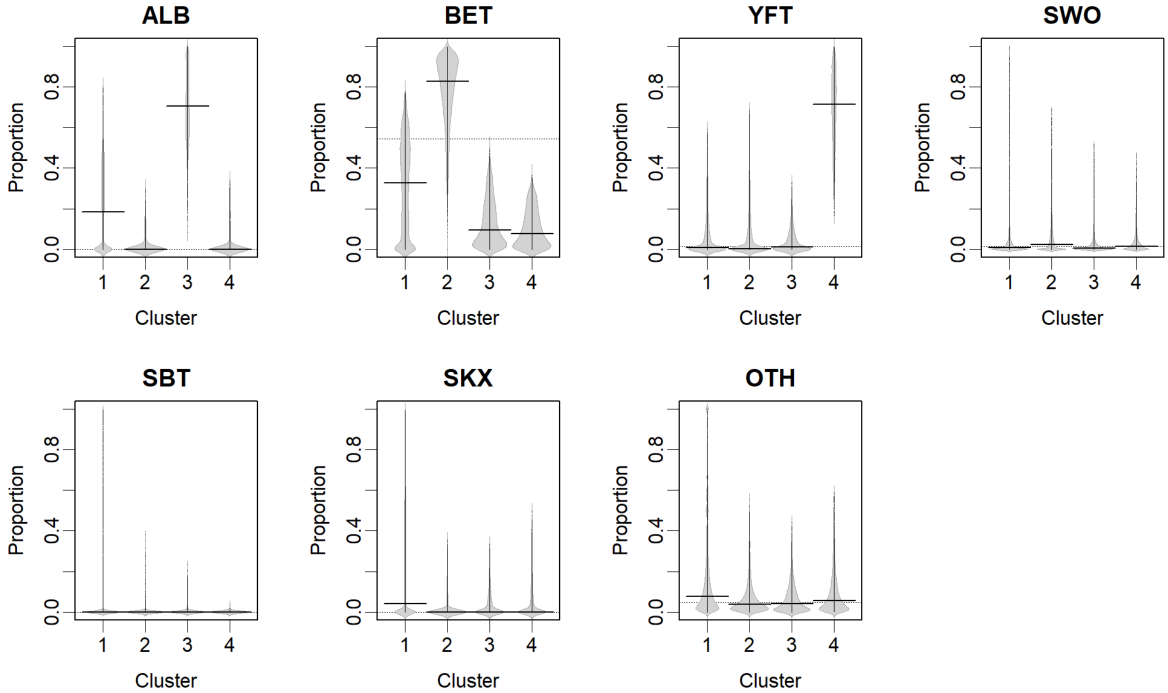


Figure 2. Beanplots for yellowfin region showing species composition by cluster for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), bluefin tuna (BFT), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH). The horizontal bars indicate the medians. (continued)

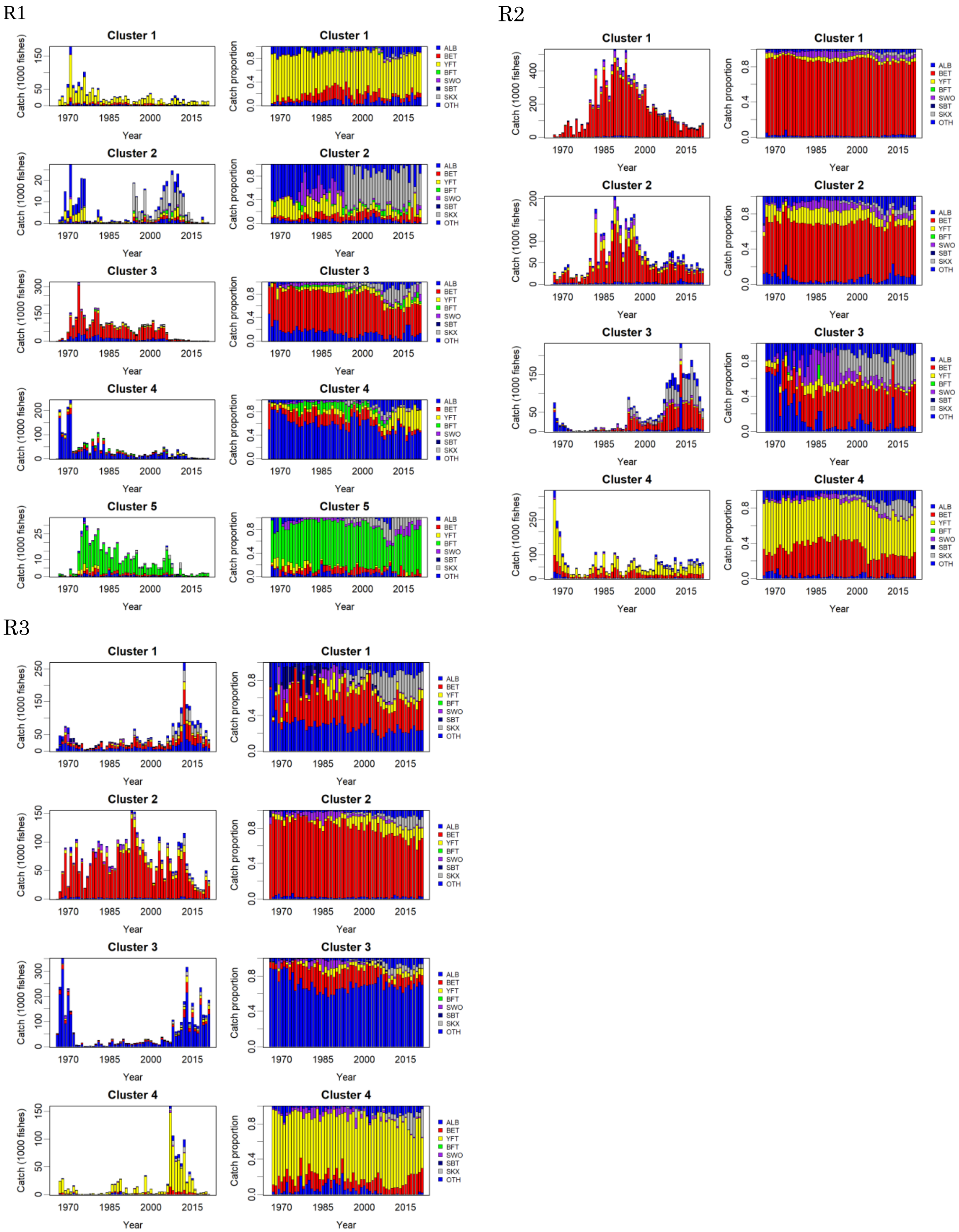
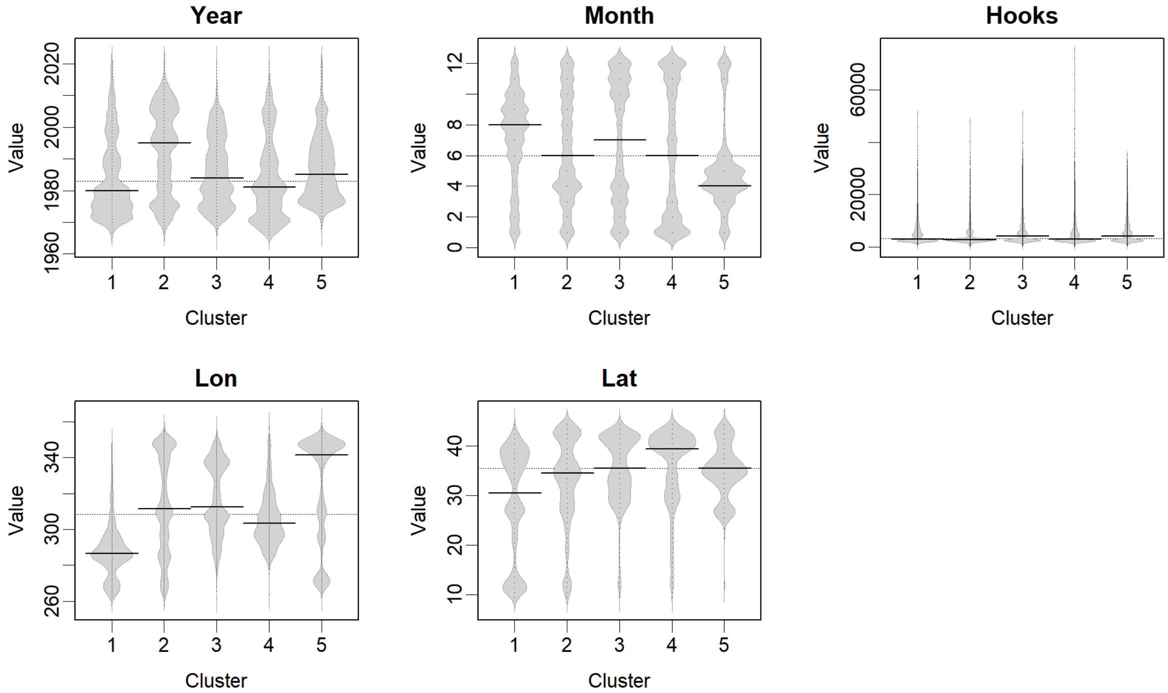


Figure 3. Annual change in species composition for albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), bluefin tuna (BFT), southern bluefin tuna (SBT), sharks (SKX) and other fish (OTH) by cluster and area.

R1



R2

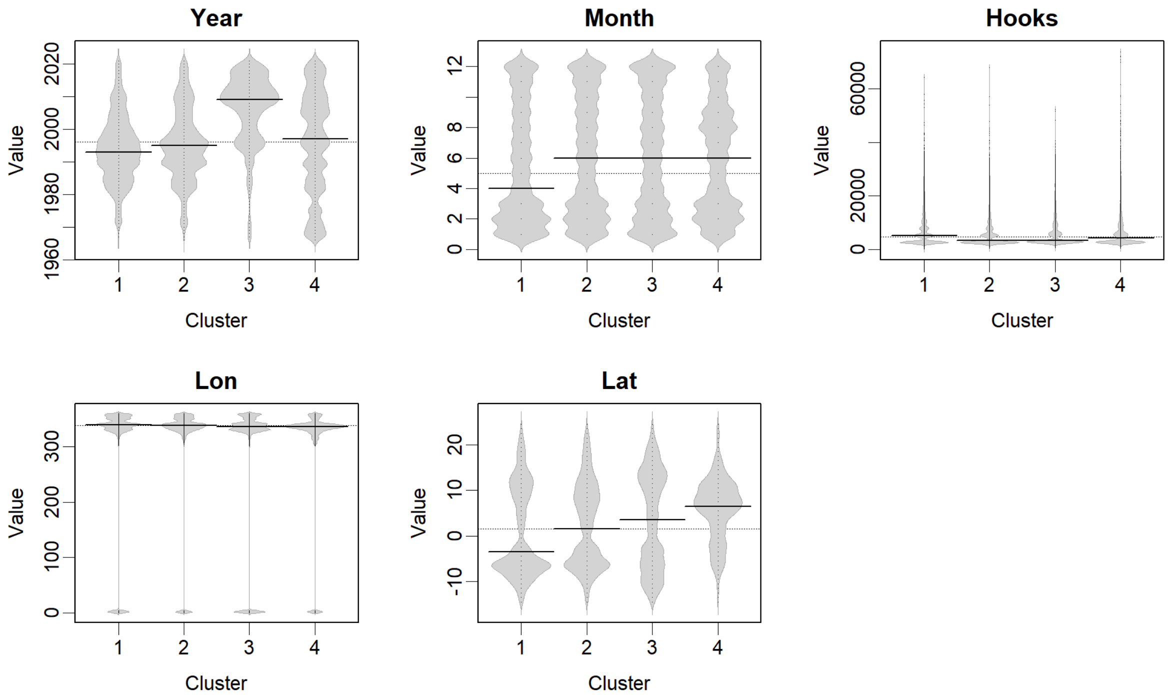


Figure 4. Beanplots for yellowfin region showing number of sets versus covariate by cluster. The horizontal bars indicate the medians.

R3

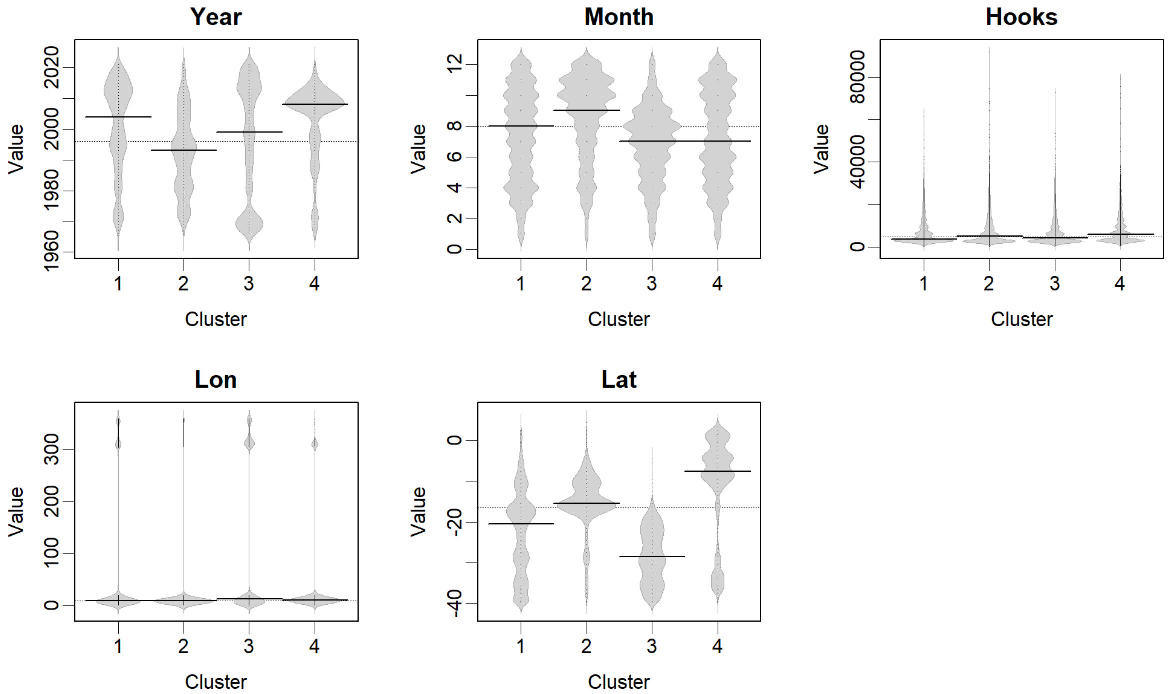


Figure 4. Beanplots for yellowfin region showing number of sets versus covariate by cluster. The horizontal bars indicate the medians. (continued)

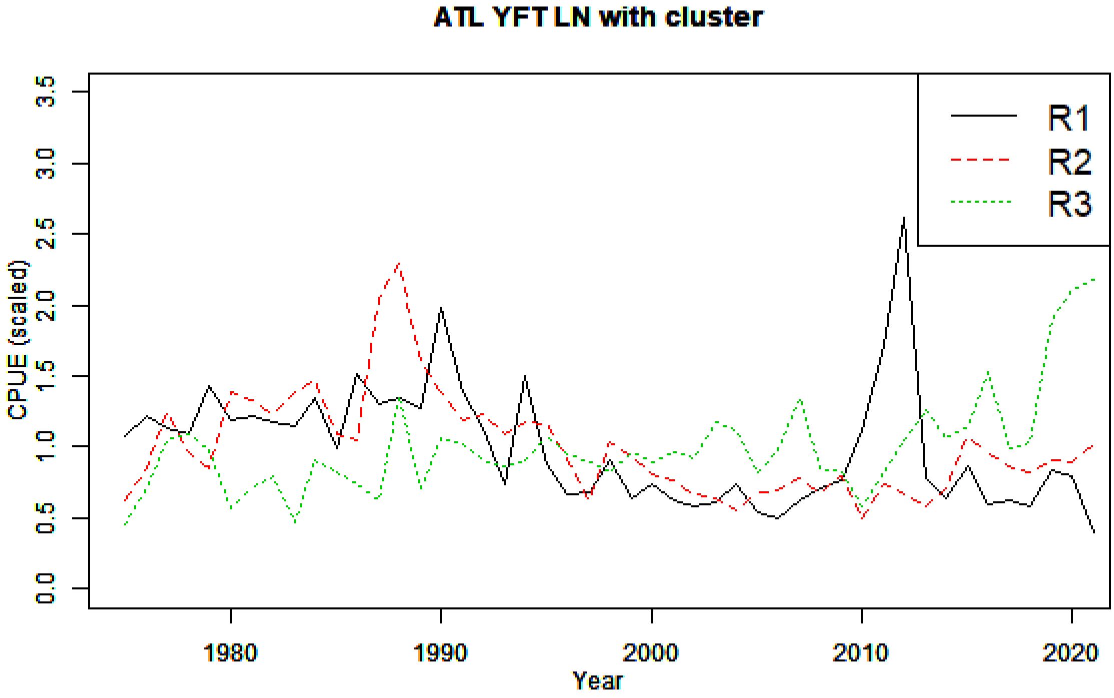


Figure 5. Trend of CPUE of yellowfin by Japanese longline for each region.

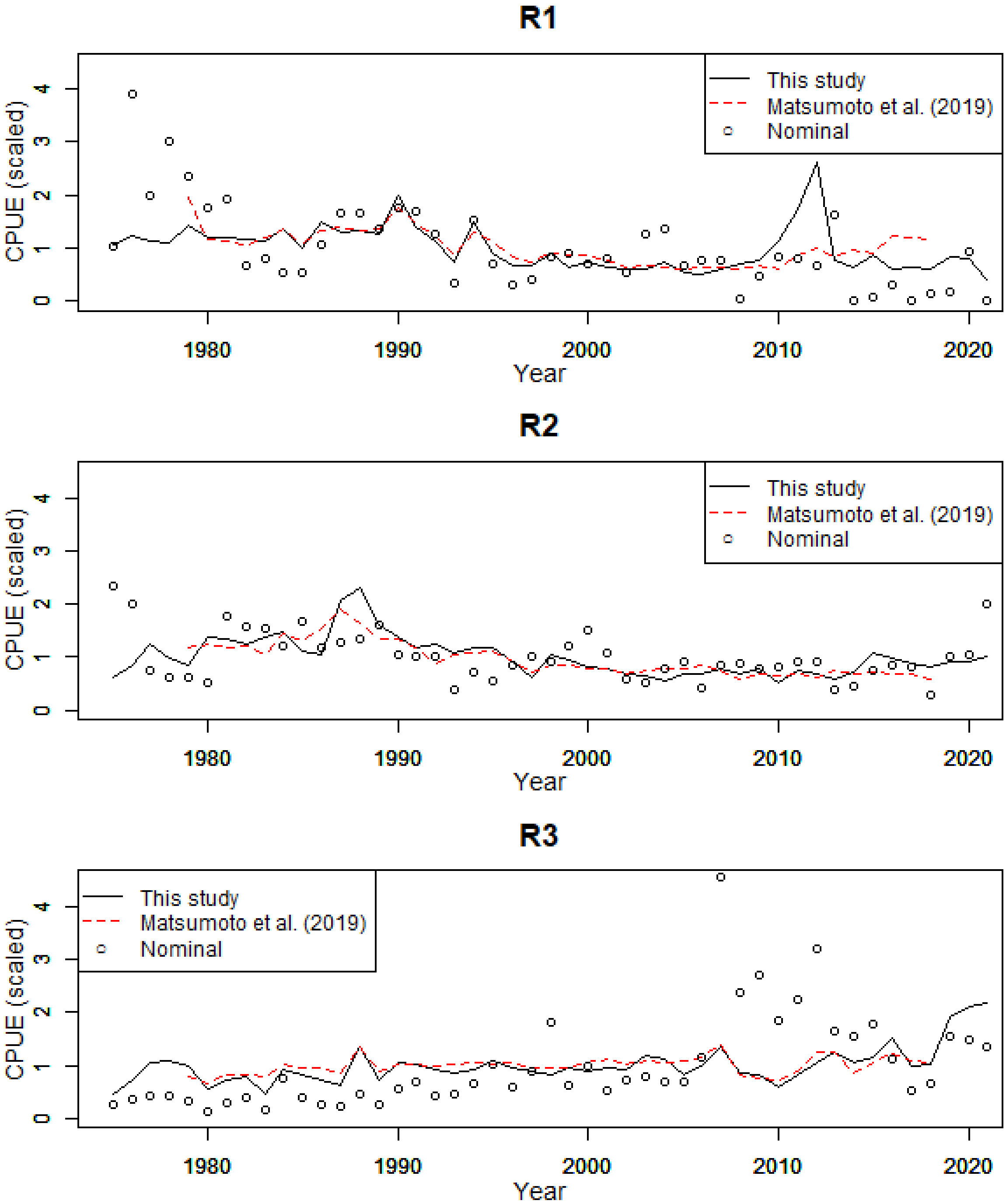


Figure 6. Comparison of CPUE series of yellowfin tuna in each area with Japanese longline CPUE based on previous collaborative study (Matsumoto et al., 2019) and nominal CPUE.

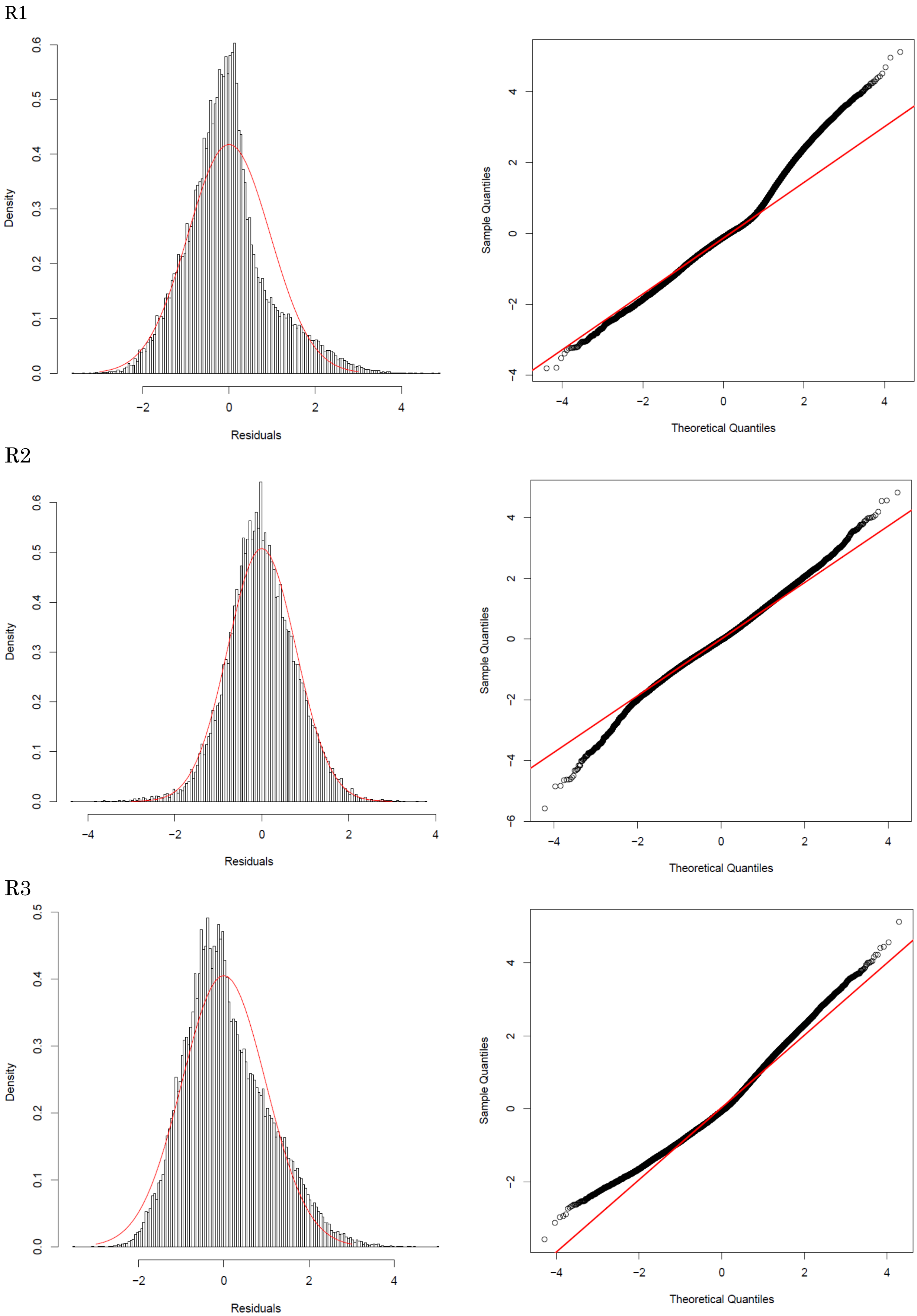


Figure 7. Standardized residuals of CPUE standardization for yellowfin.

R1

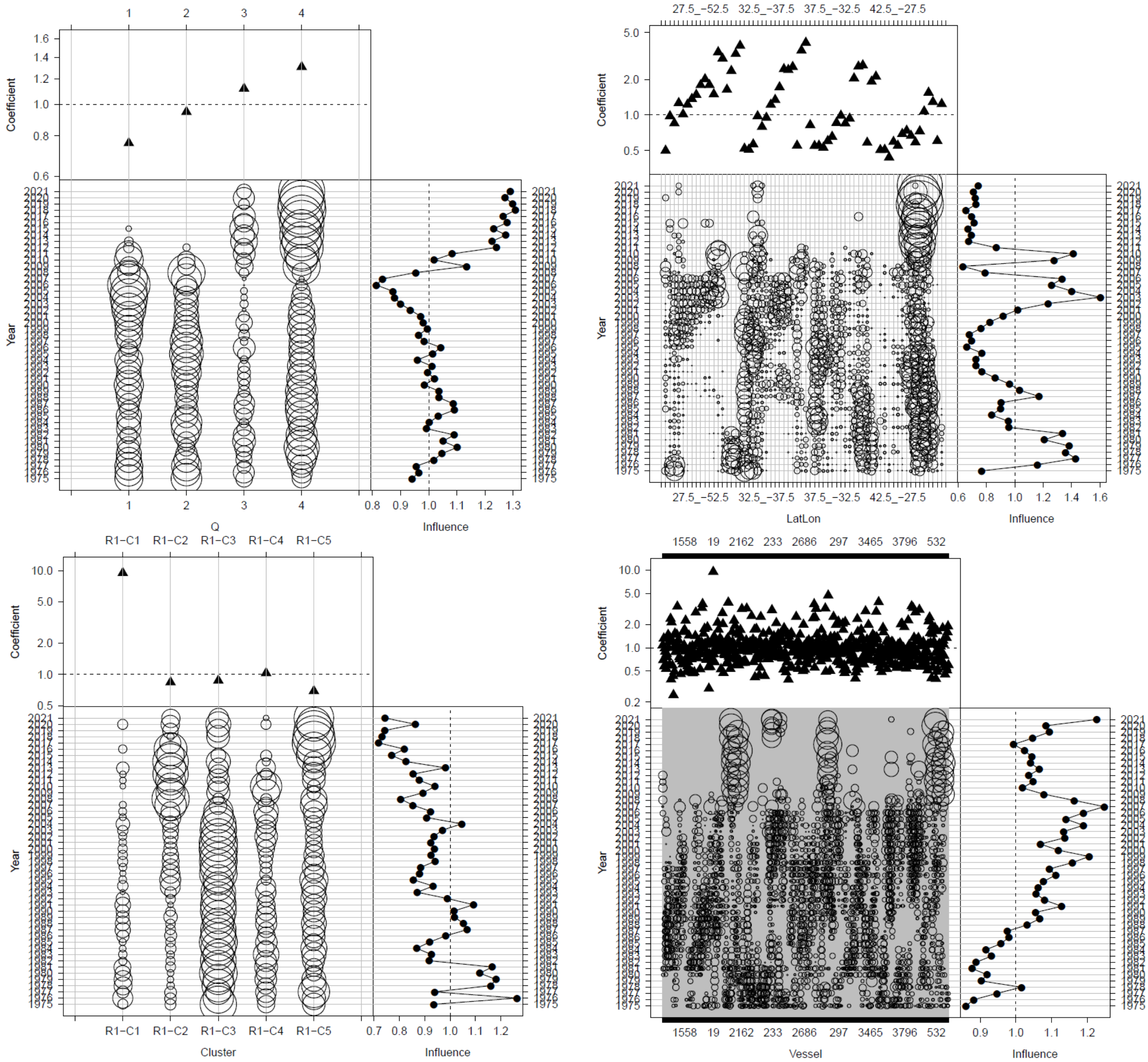


Figure 8. Influence plot for CPUE standardization for yellowfin.

R2

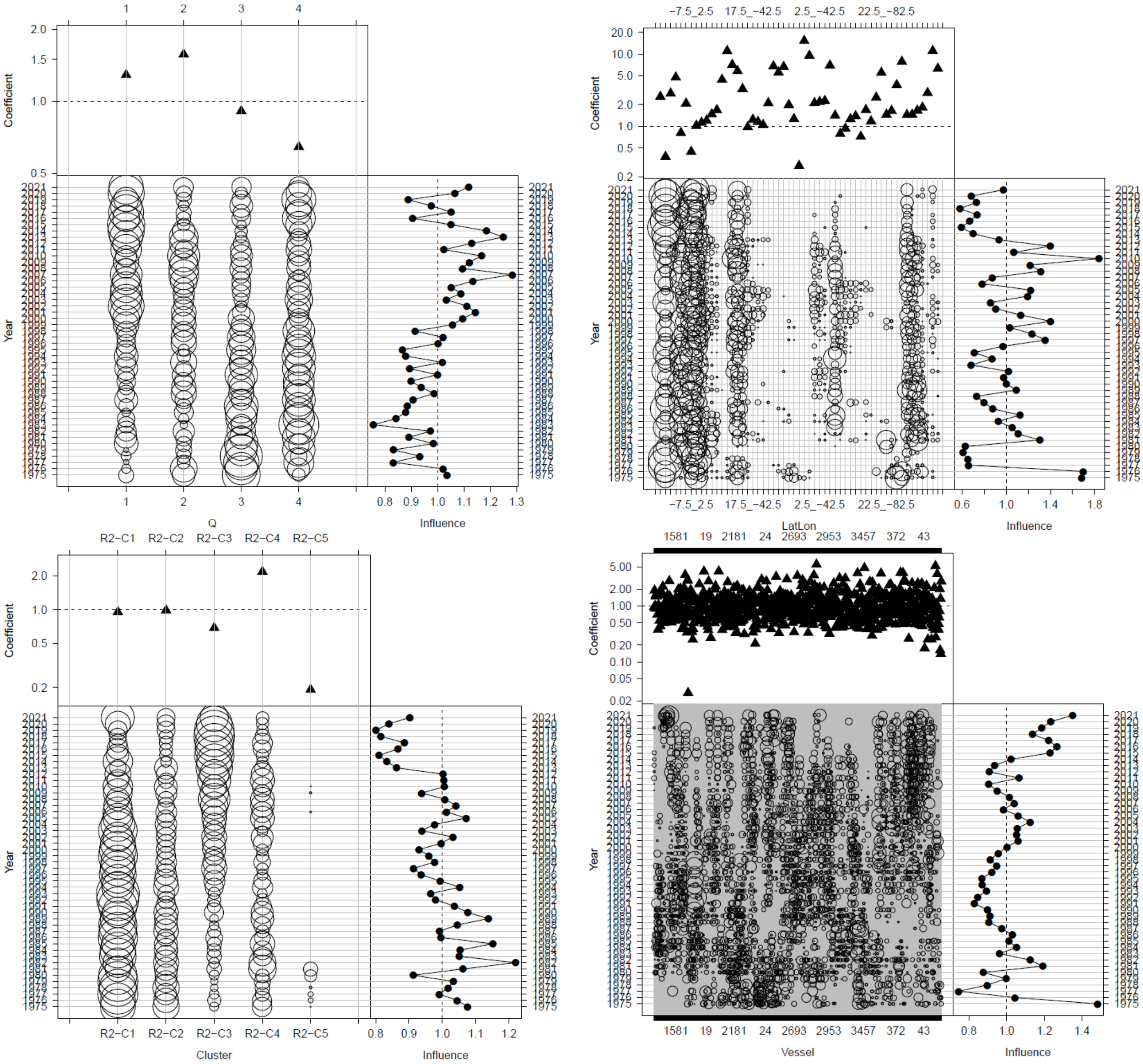


Figure 8. Influence plot for CPUE standardization for yellowfin. (continued)

R3

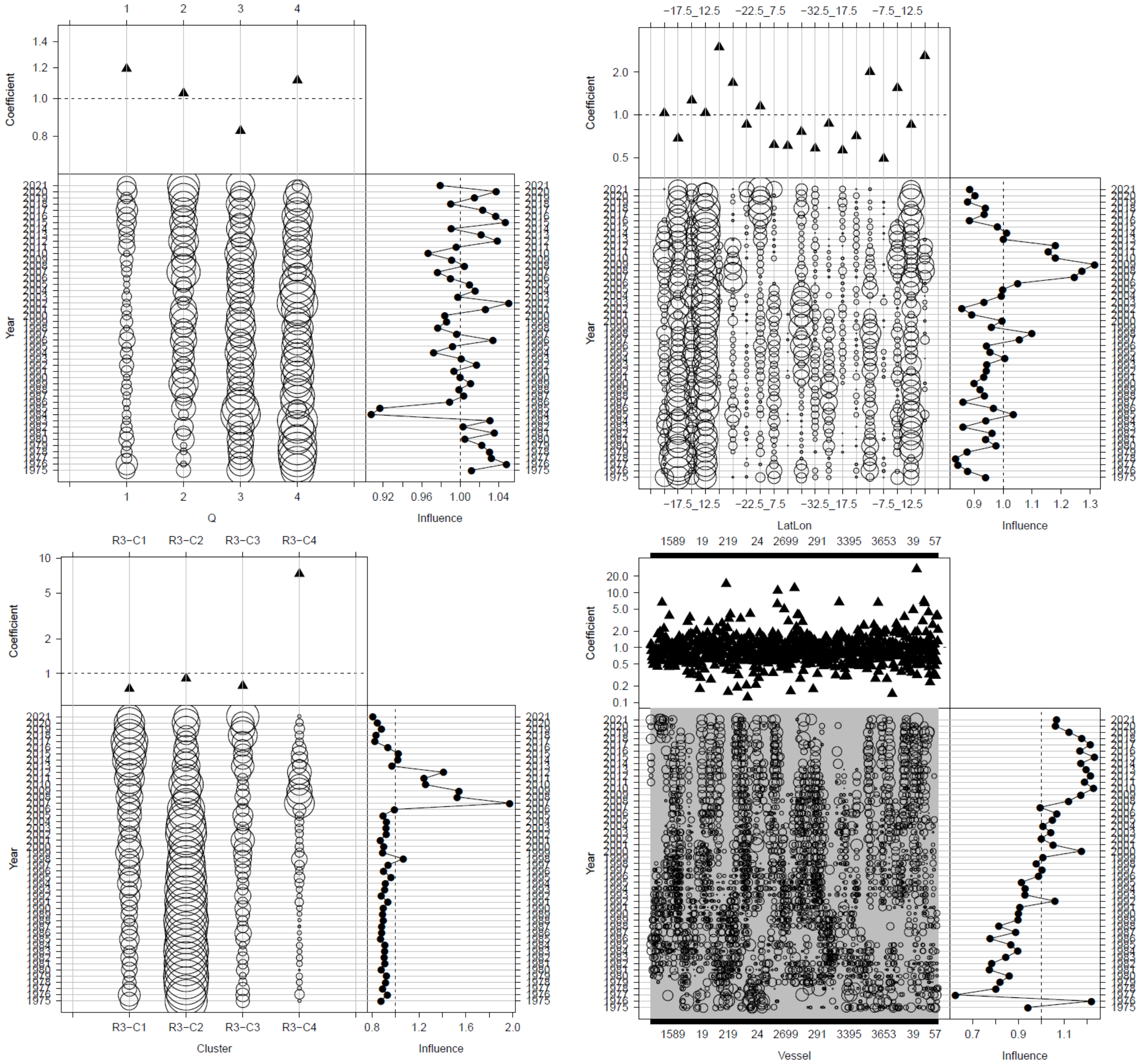


Figure 8. Influence plot for CPUE standardization for yellowfin. (continued)