Joint longline CPUE for yellowfin tuna in the Indian Ocean by the Japanese, Korean and Taiwanese longline fishery

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Abstract

Joint CPUE for yellowfin tuna in the Indian Ocean by the Japanese, Korean and Taiwanese longline fishery was standardized for 1975-2023 by GLM (delta-lognormal). 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 blocks. CPUEs were successfully created based on aggregated data or subsampled operational data. Standardized CPUEs usually showed decreasing trend but was constant or increasing in recent years.

1. Introduction

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 IOTC stock assessment. Also during 2017-2019 joint CPUE analysis workshops were held and joint CPUE for yellowfin and bigeye tuna were created (Hoyle et al., 2017; 2018, 2019).

A new collaborative study for developing the abundance index started in late 2019 by Japanese, Korean and Taiwanese scientists, and CPUE analysis for Indian Ocean yellowfin tuna was conducted in 2021 (Kitakado et al., 2021). In 2022, CPUE analysis for Indian Ocean bigeye tuna was held (Kitakado et al., 2022). In these analyses, only aggregated data were used because in-person meeting could not be held due to Covid-19 pandemic and sharing operational data was not done according to the agreement. Joint CPUE analysis meeting (in-person) in this collaborative study was held in May 2024, which enabled to share operational data. This document reports the standardization of yellowfin tuna joint CPUE (Japanese, Korean and Taiwanese longline fishery) in the Indian Ocean created in this year's collaborative study.

2. Materials and methods

Catch and effort data used:

Operational level (set by set) longline logbook data with vessel ID by the Japanese, Taiwanese and Korean longline fishery were used for cluster analysis mentioned below. Japanese data were available for 1975-2023, with includes vessel ID. Taiwanese data were available for the indices for the period 2005-2023. Korean operational data were available for 1979 to 2023. Data for 2023 are preliminary for all the fleets. These data include operation date, fishing location, vessel ID, fishing effort (number of hooks per set), catch in number and so on.

Each set was allocated to subregion (subarea) (Fig. **1**). These regions are the same as those usen for SS3 model in the previous (2021) IOTC yellowfin tuna stock assessment.

Cluster analysis
We clustered the data using the approach described by Kitakado et al. (2021), which used Euclidean as the distance measure and Ward's minimum variance as the agglomeration method. Clustering was conducted separately by each fleet and region (Fig. **1**) for better reflect targeting by each fleet. 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 analyses for the previous meetings (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 centers.

GLM (Generalized Linear Model)
After cluster analysis, cluster numbers were assigned to operational catch and effort data. For shortening calculation time, aggregated data by year, month, vessel ID, cluster number and 5 degree latitude and longitude was also created. These data sets were used for CPUE standardization. Subsampling of operational data by 10-30% (in each latitude-longitude and year-quarter) was conducted in the CPUE analyses for shortening calculation time.

GLM (generalized linear models) that assumed a delta-lognormal distribution was conducted considering high zero catch ratio (Fig. **2**). This employed a binomial distribution for the probability w of catch rate being zero and a probability distribution *f(y)* , where y was log(catch/hooks set), for non-zero (positive) catch rates. The index estimated for each year-quarter was the product of the year effects for the two model components, $(1-w).E(y|y\neq 0)$.

$$\Pr(Y=y)=\begin{cases} w, & y=0 \\ (1-w)f(y) & otherwise \end{cases}$$

<u>Annual CPUE</u>

$\mathrm{g}(w)=(CPUE=0)\sim \mathrm{yr}+\ \mathrm{qtr}+\mathrm{latlong5}+cluster+\epsilon,+\epsilon$, where g is the logistic function.

$\mathrm{f}(y)=CPUE\sim \mathrm{yr}+\ \mathrm{qtr}+\mathrm{vessid}+\mathrm{latlong5}+cluster+\epsilon,+\epsilon$, for nonzero sets

<u>Quarterly CPUE</u>

$\mathrm{g}(w)=(CPUE=0)\sim \mathrm{yrqtr}+\mathrm{vessid}+\mathrm{latlong5}+cluster+\epsilon,+\epsilon$, where g is the logistic function.

$\mathrm{f}(y)=CPUE\sim \mathrm{yrqtr}+\mathrm{vessid}+\mathrm{latlong5}+cluster+\epsilon,+\epsilon$, for nonzero sets

where *yr*: effect of year, *q*tr: effect of quarter, yr*q*tr: effect of year-quarter; *vess*id: effect of vessel ID; *latlon*5: effect of five degree latitude and longitude; cluster: effect of cluster; ϵ: error term

CPUE standardization was conducted separately by region shown in Fig. **1**. Also, CPUE standardization based on combined area ("R1+R2 and R3+R4", or "R1+R2+ R3 and R4") was also conducted.

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
Table **1** shows list of CPUE indices created in the collaborative study. CPUE was successfully created based on aggregated data or subsampled operational data. Creating CPUE with full operational data was not successful due to time-consuming calculation during the planned meeting period (one week). In several analyses, CPUE indices were

created based on estimated parameters and so the index in the first year (1975) or year-quarter (1975 first quarter) is not available. Species compositions were plotted by cluster for each region and year (**Fig. 3**). Dominant species differed depending on clusters, and yellowfin tuna was dominant in several clusters. Number of clusters were 4 or 5 for each region.

Fig. 4-Fig. 8 show the trend of yellowfin CPUE in each region. As for 4 area model, CPUE shows similar trend of decreasing and then constant in R1, R3 and R4 whereas it was comparatively constant throughout the period in R2. As for 2 area (R1+R2 and R3+R4) model, both CPUEs show decreasing trend until around 2010 and then became constant and is increasing in recent years. As for 2 area (R1+R2+R3 and R4) model, both CPUEs show decreasing trend but steeper decrease is observed in R2 (original R4).

Fig. 9-Fig. 11 show distribution of standardized residuals and QQ plots. It seems that the distributions are not largely skewed. **Fig. 12-Fig. 14** show 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. References

Hoyle, S., Chang, Y., Kim, D. N., Lee, S., Matsumoto, T., Satoh, K. and Yeh, Y. (2016) Collaborative study of tropical tuna CPUE from multiple Indian Ocean longline fleets in 2016. IOTC-2016-WPTT18-14.

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Table 1. Available indices for yellowfin tuna joint CPUE.

Area	Time step	Data resolution	Subsampling rate	Period
4 area	Year	Operational	20%	1976-2023
4 area	Quarter	Aggregated	100%	1975 (2nd quarter)-2023
2 area (R1+R2 and R3+R4)	Year	Operational	30%	1976-2023
2 area (R1+R2+ R3 and R4)	Year	Operational	30%	1976-2023
2 area (R1+R2+ R3 and R4)	Quarter	Operational	30%	1975 (2nd quarter)-2023

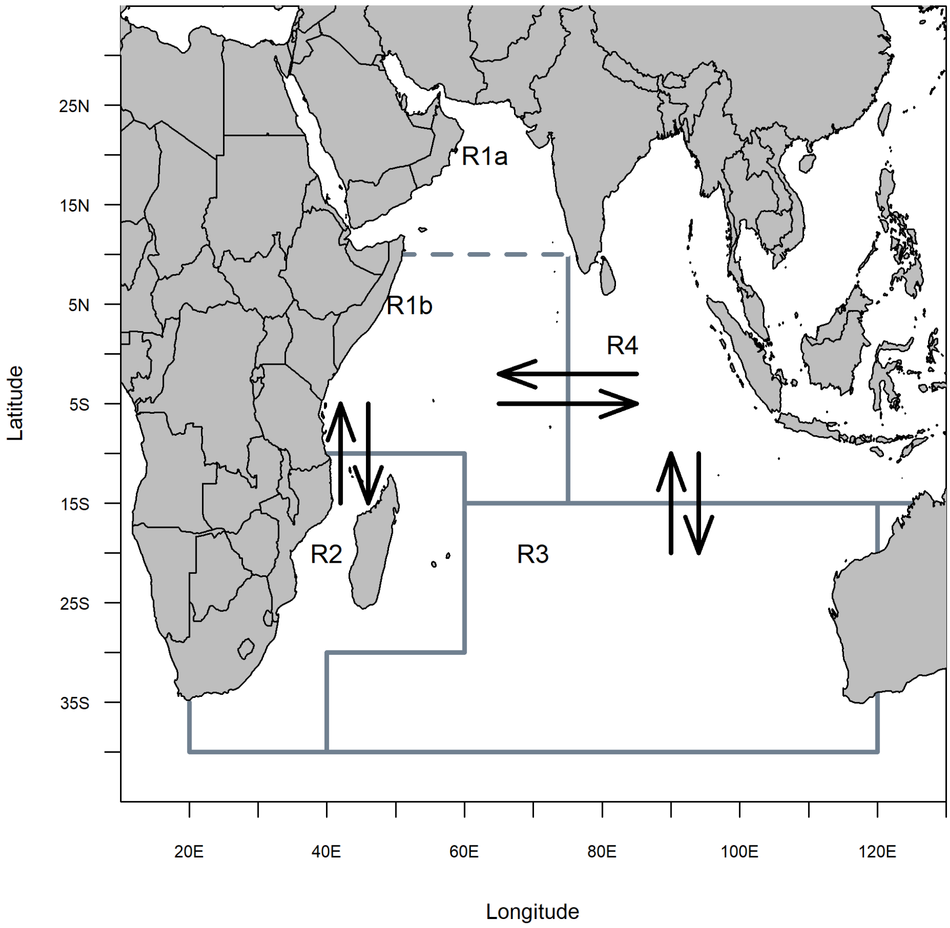
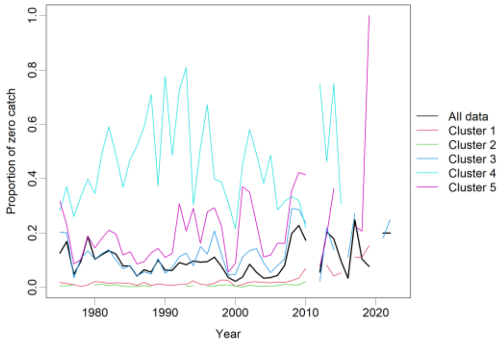


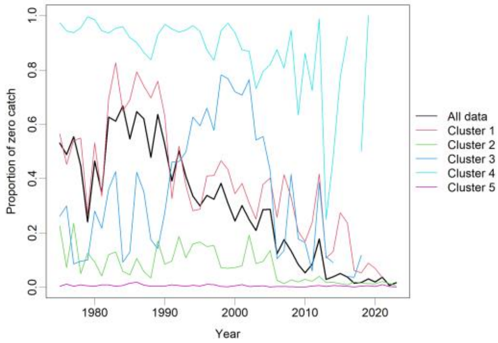
Fig. 1. Definition of areas used in this study. R1a and R1b were combined as R1. Note: for 2 area model, "R1+R2+R3 (new R1) and R4 (new R2)" or "R1+R2 (new R1) and R3+R4 (new R2)" was used.

(a) Japan

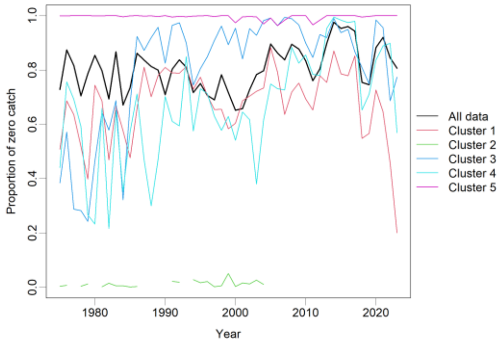
R1



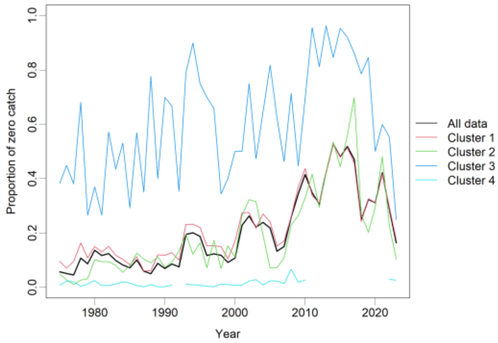
R2



R3

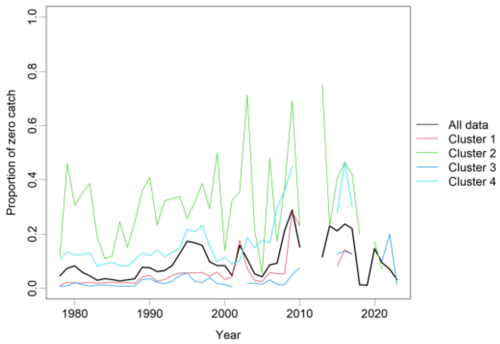


R4

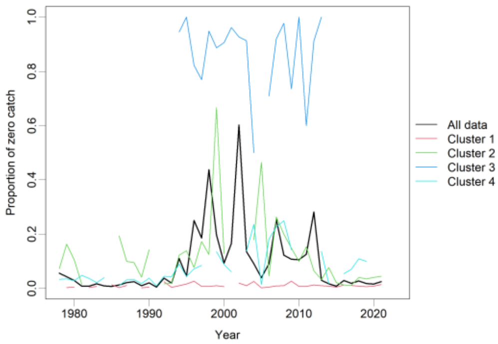


(b) Korea

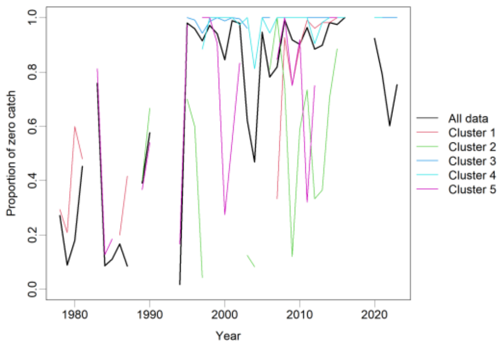
R1



R2



R3



R4

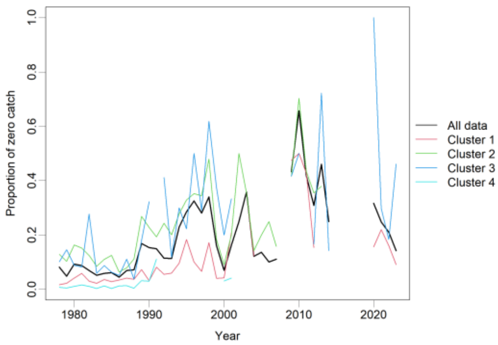
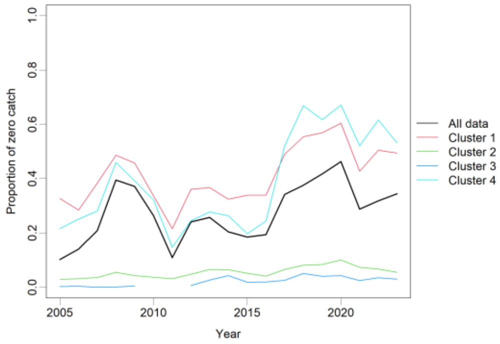


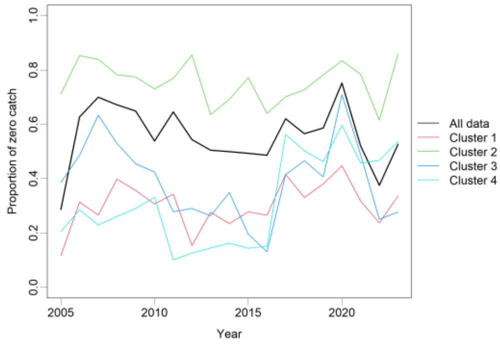
Fig. 2. Zero catch ratio for yellowfin tuna in the data used for CPUE standardization.

(c) Taiwan

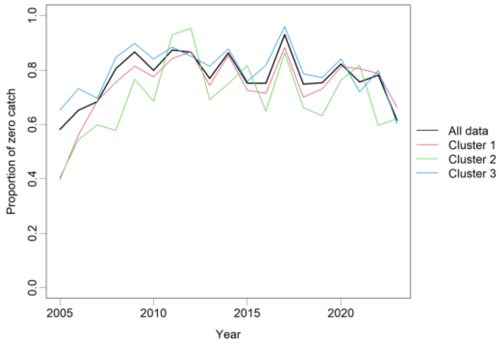
R1



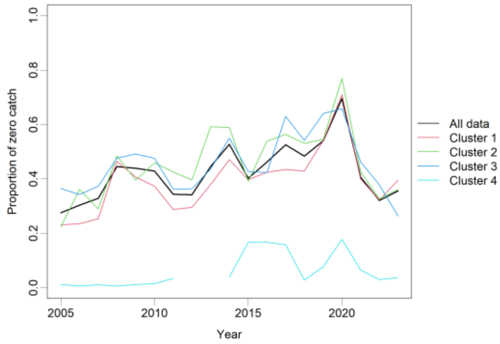
R2



R3



R4



. Zero catch ratio for yellowfin tuna in the data used for CPUE standardization. (continued)-

(a) Japan

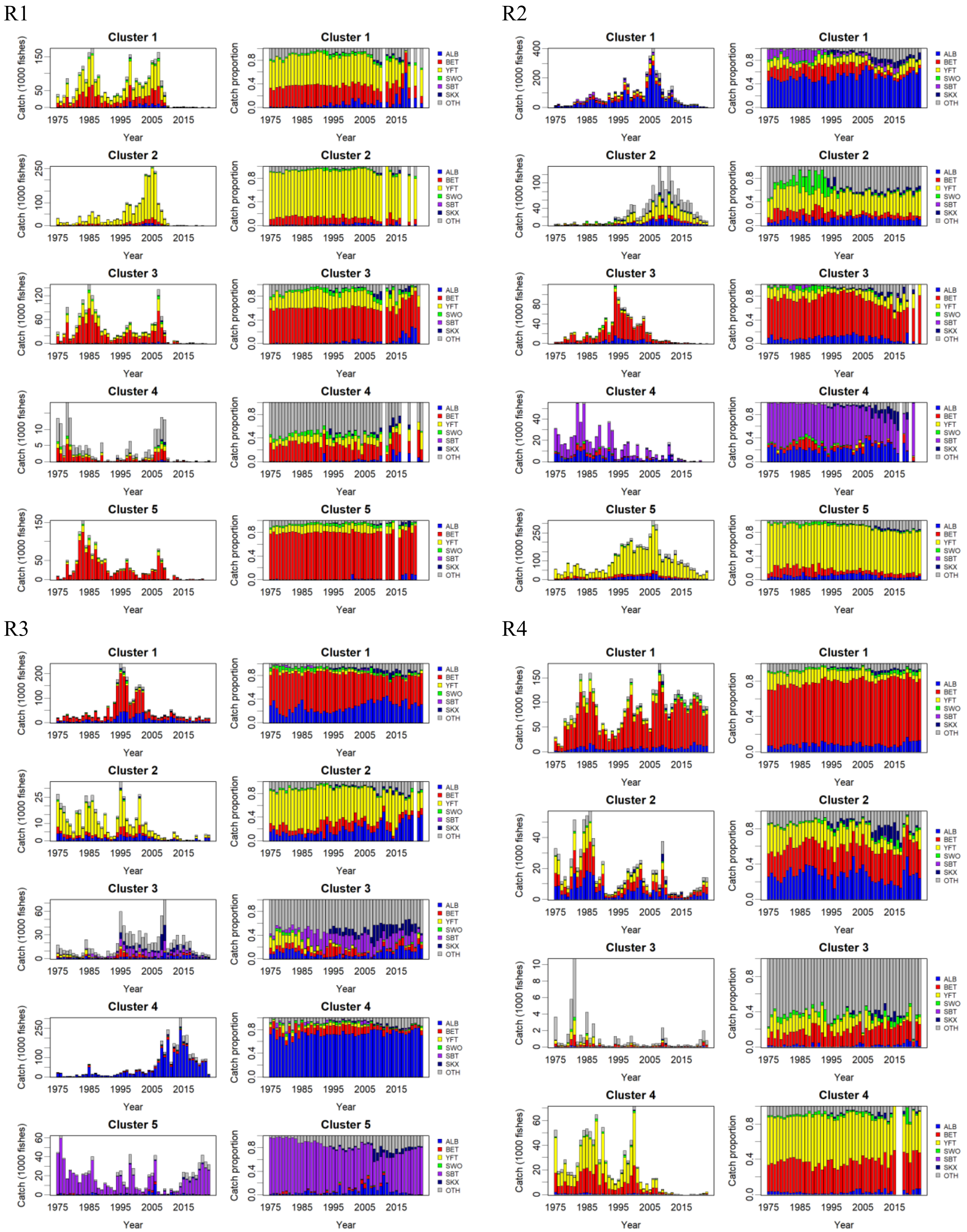
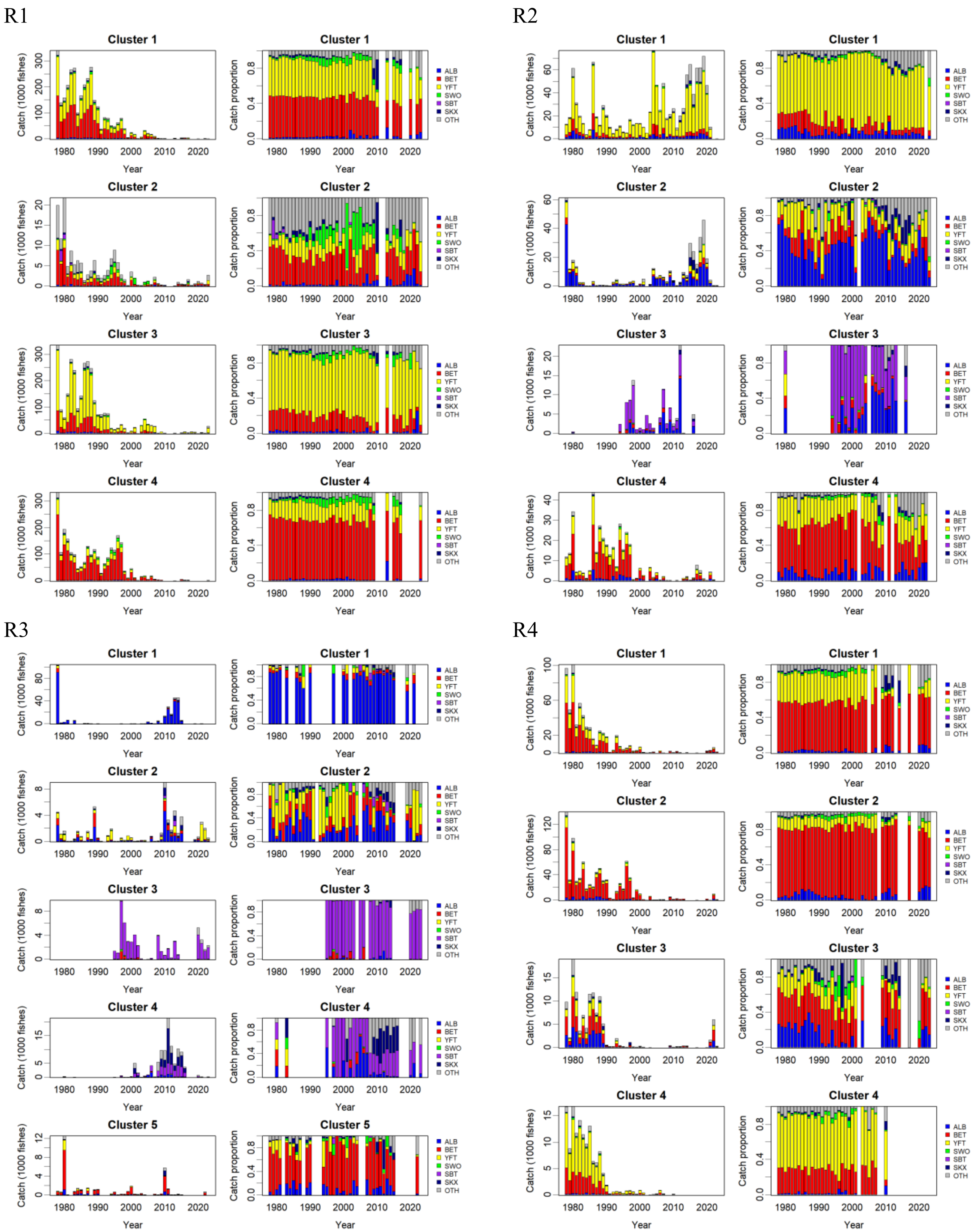


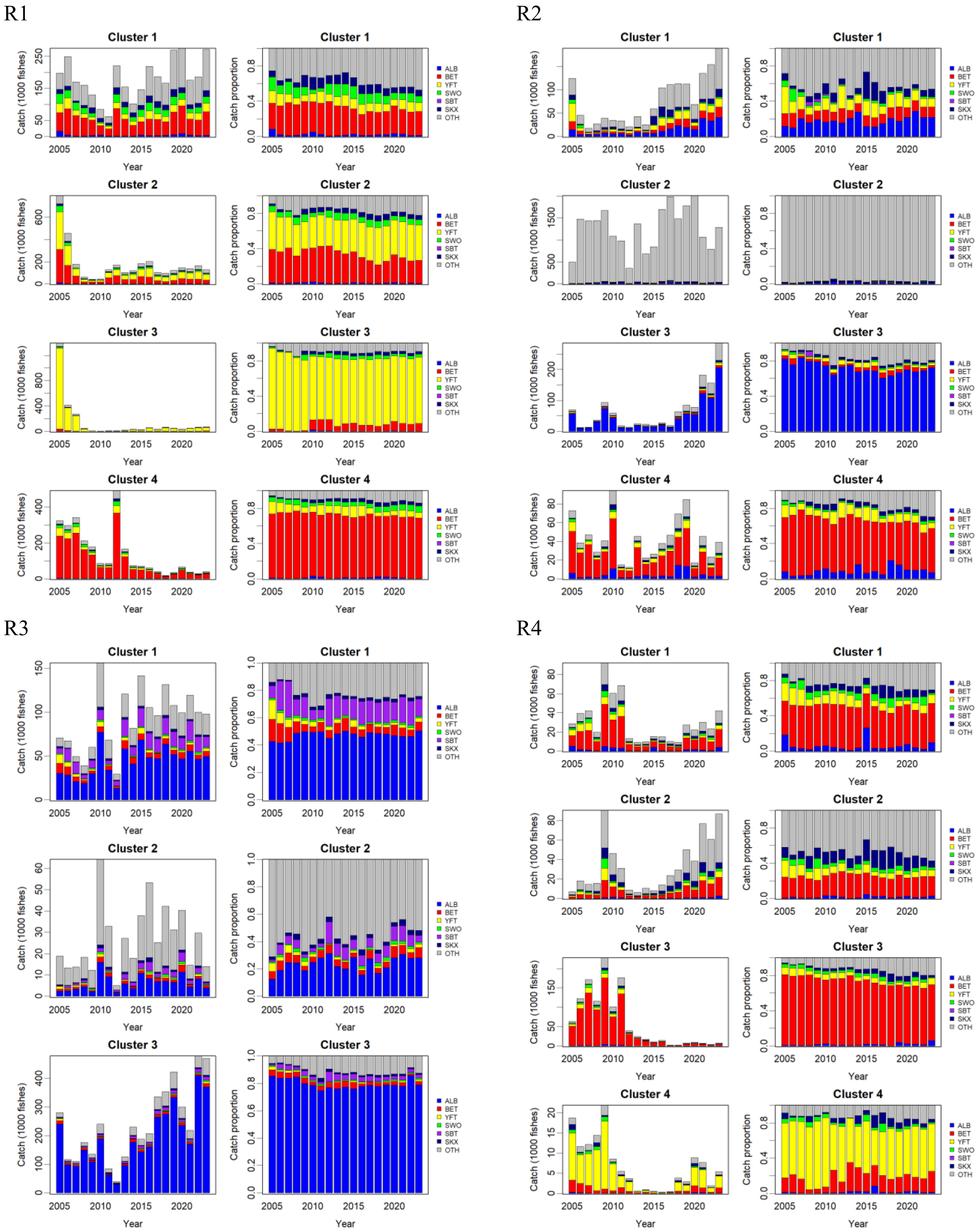
Fig. 3. Species composition of the catch for each cluster.

(b) Korea



. Species composition of the catch for each cluster. (continued)

(c) Taiwan



. Species composition of the catch for each cluster. (continued)

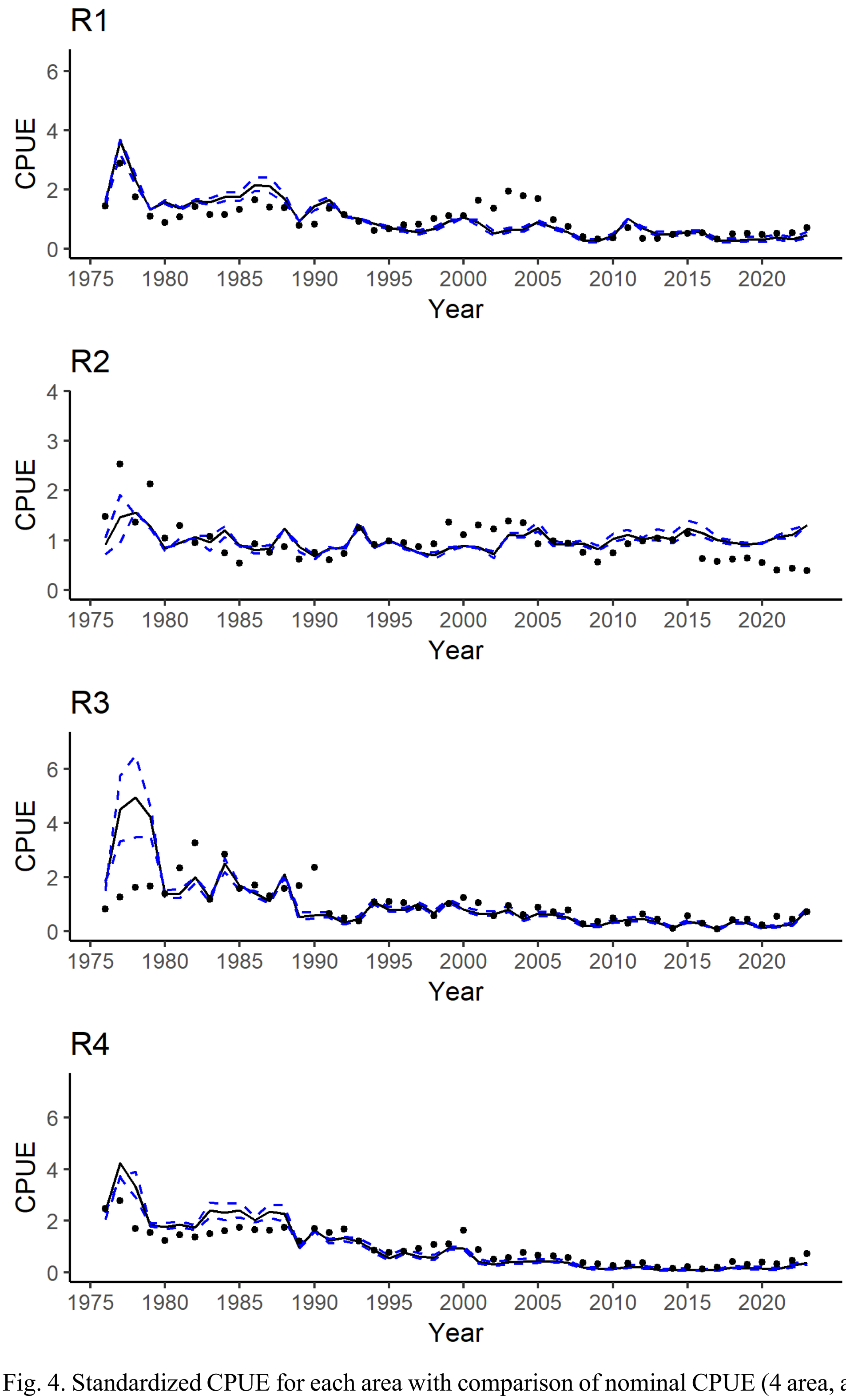


Fig. 4. Standardized CPUE for each area with comparison of nominal CPUE (4 area, annual). Dashed lines show 95% confidence interval, and dots show nominal CPUE.

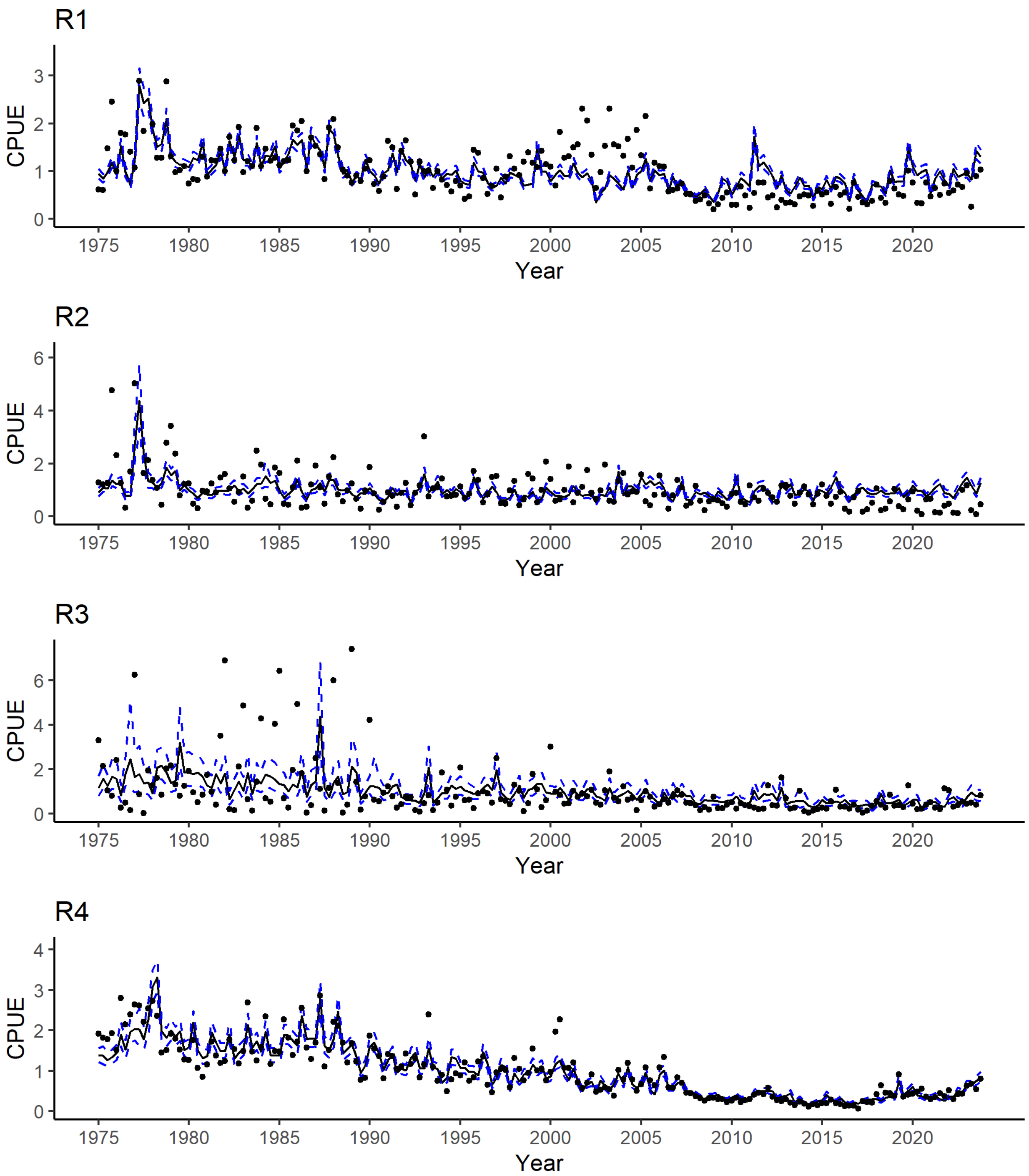


Fig. 5. Standardized CPUE for each area with comparison of nominal CPUE (4 area, quarterly). Dashed lines show 95% confidence interval, and dots show nominal CPUE.

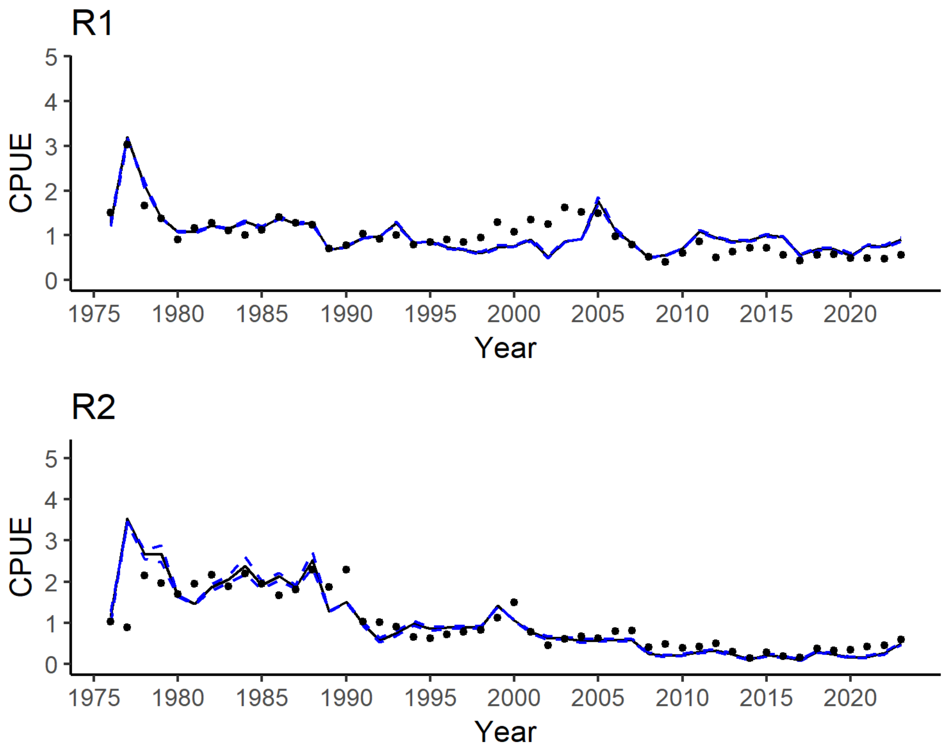


Fig. 6. Standardized CPUE for each area with comparison of nominal CPUE (2 area (R1+R2 and R3+R4), annual). Dashed lines show 95% confidence interval, and dots show nominal CPUE.

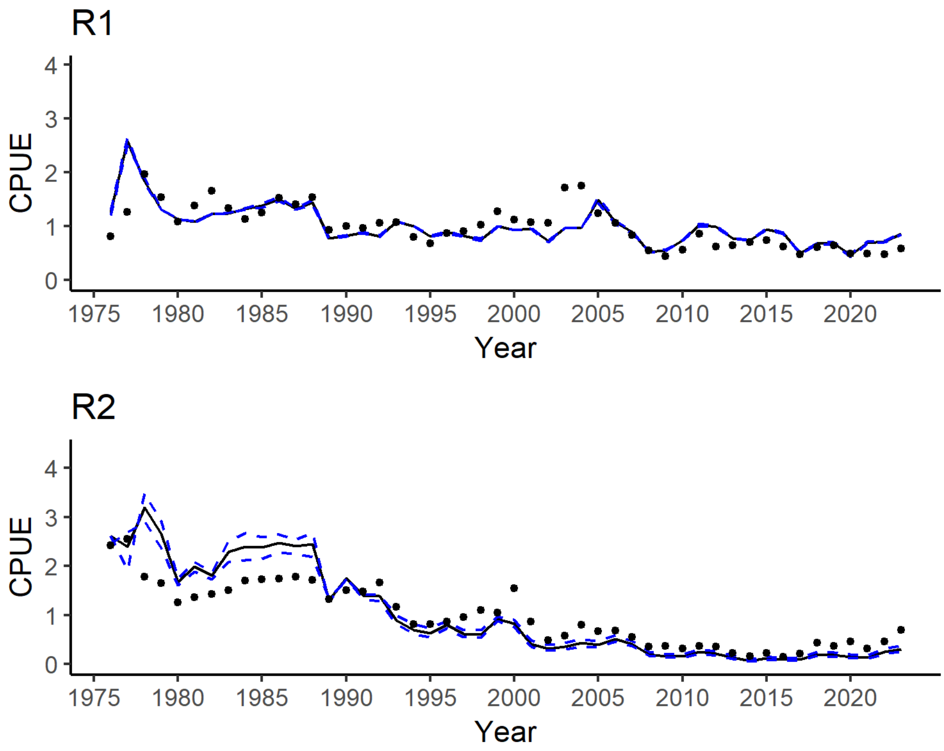


Fig. 7. Standardized CPUE for each area with comparison of nominal CPUE (2 area (R1+R2+ R3 and R4), annual). Dashed lines show 95% confidence interval, and dots show nominal CPUE.

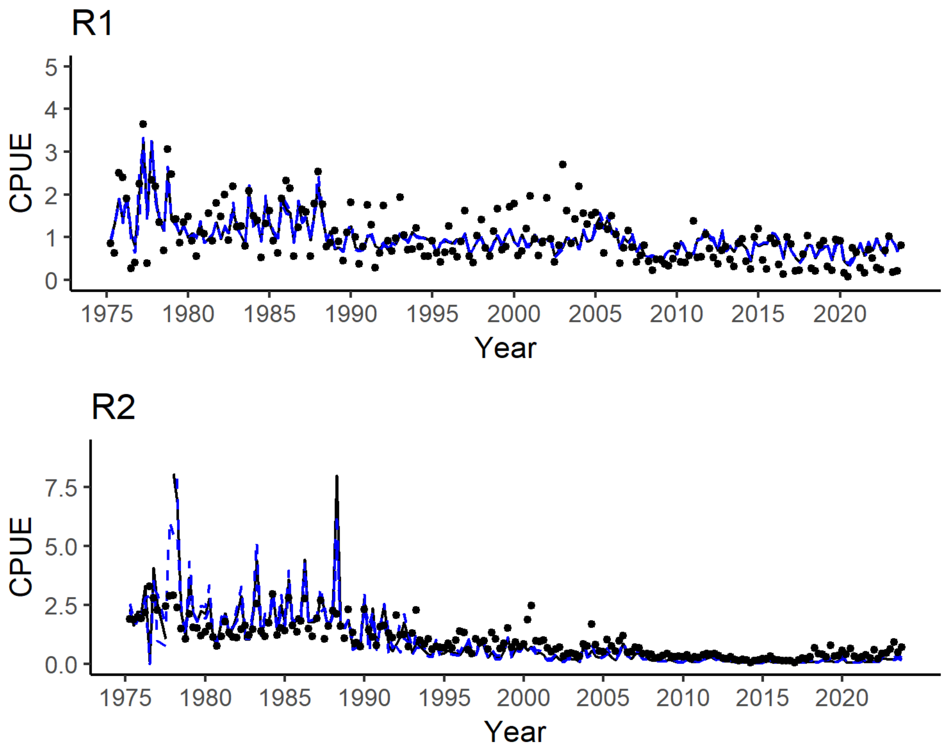
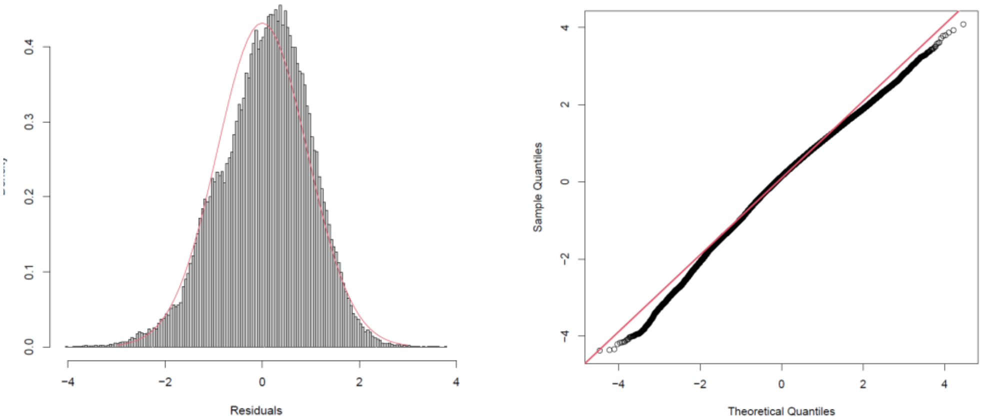
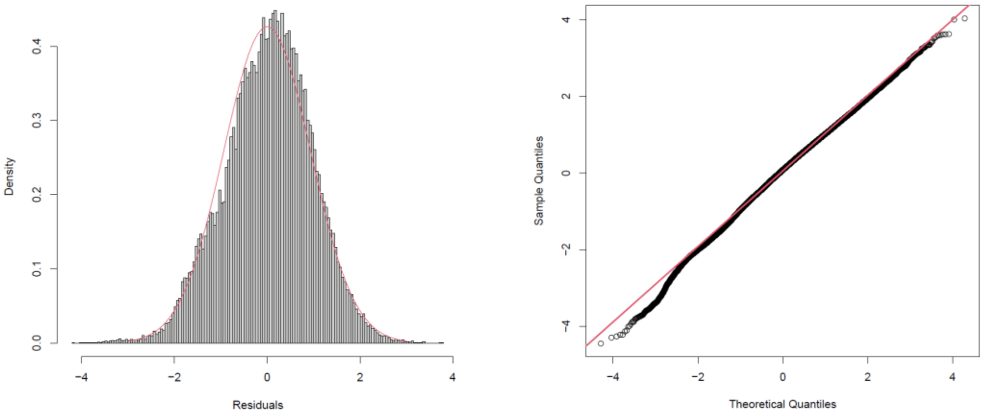


Fig. 8. Standardized CPUE for each area with comparison of nominal CPUE (2 area (R1+R2+ R3 and R4), quarterly). Dashed lines show 95% confidence interval, and dots show nominal CPUE.

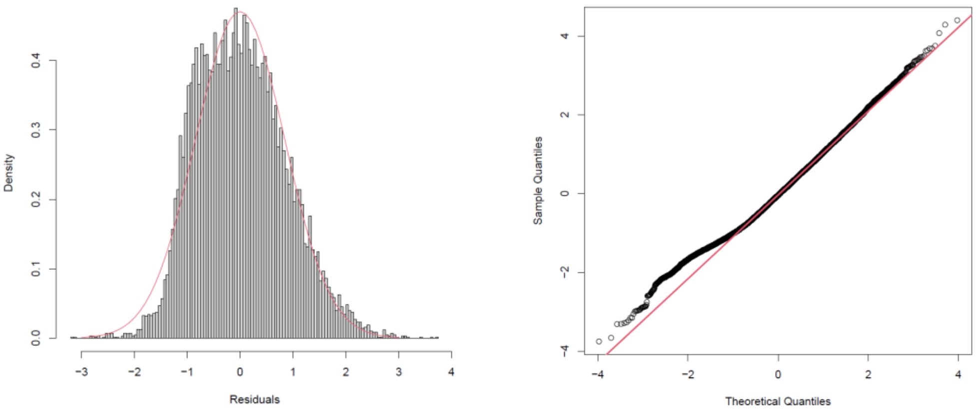
R1



R2



R3



R4

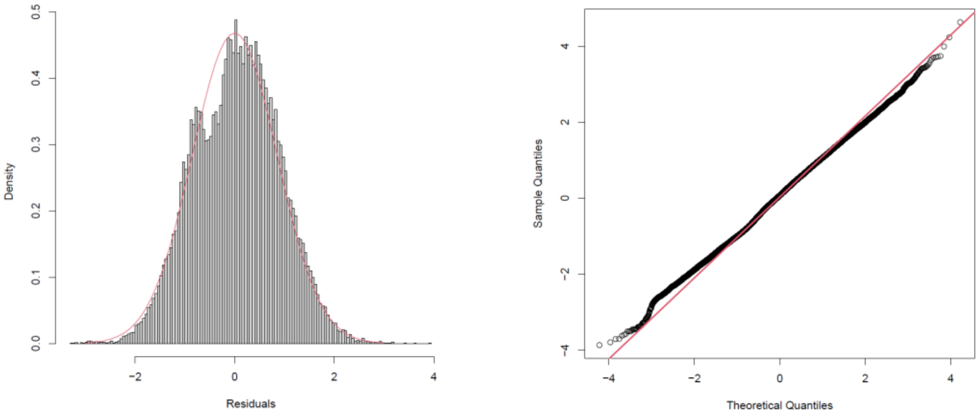


Fig. 9. Standardized residuals of year based CPUE standardization for each of four areas expressed as histograms and QQ plots (4 area model, annual).

R1

R2

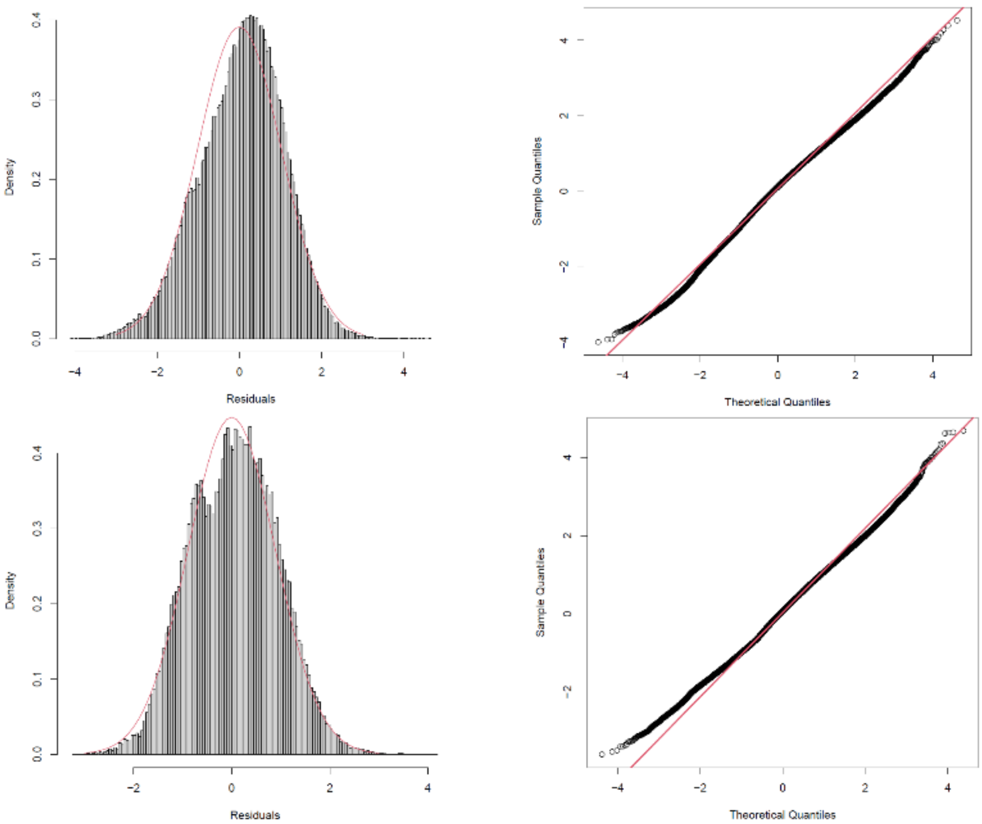
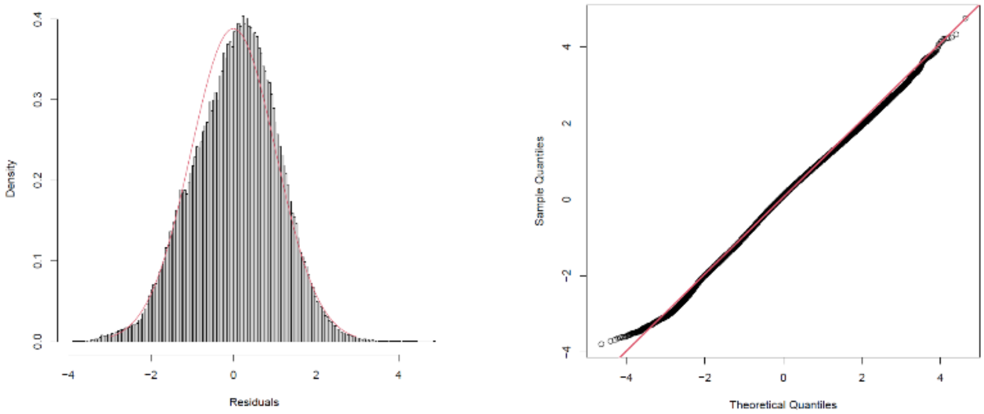


Fig. 10. Standardized residuals of year based CPUE standardization for each of four areas expressed as histograms and QQ plots (2 area (R1+R2 and R3+R4), annual).

R1



R2

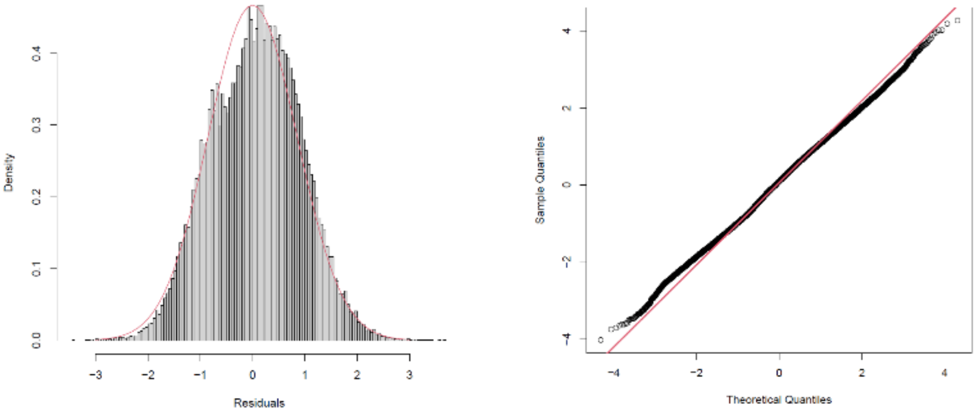


Fig. 11. Standardized residuals of year based CPUE standardization for each of four areas expressed as histograms and QQ plots (2 area (R1+R2+ R3 and R4), annual).

R1

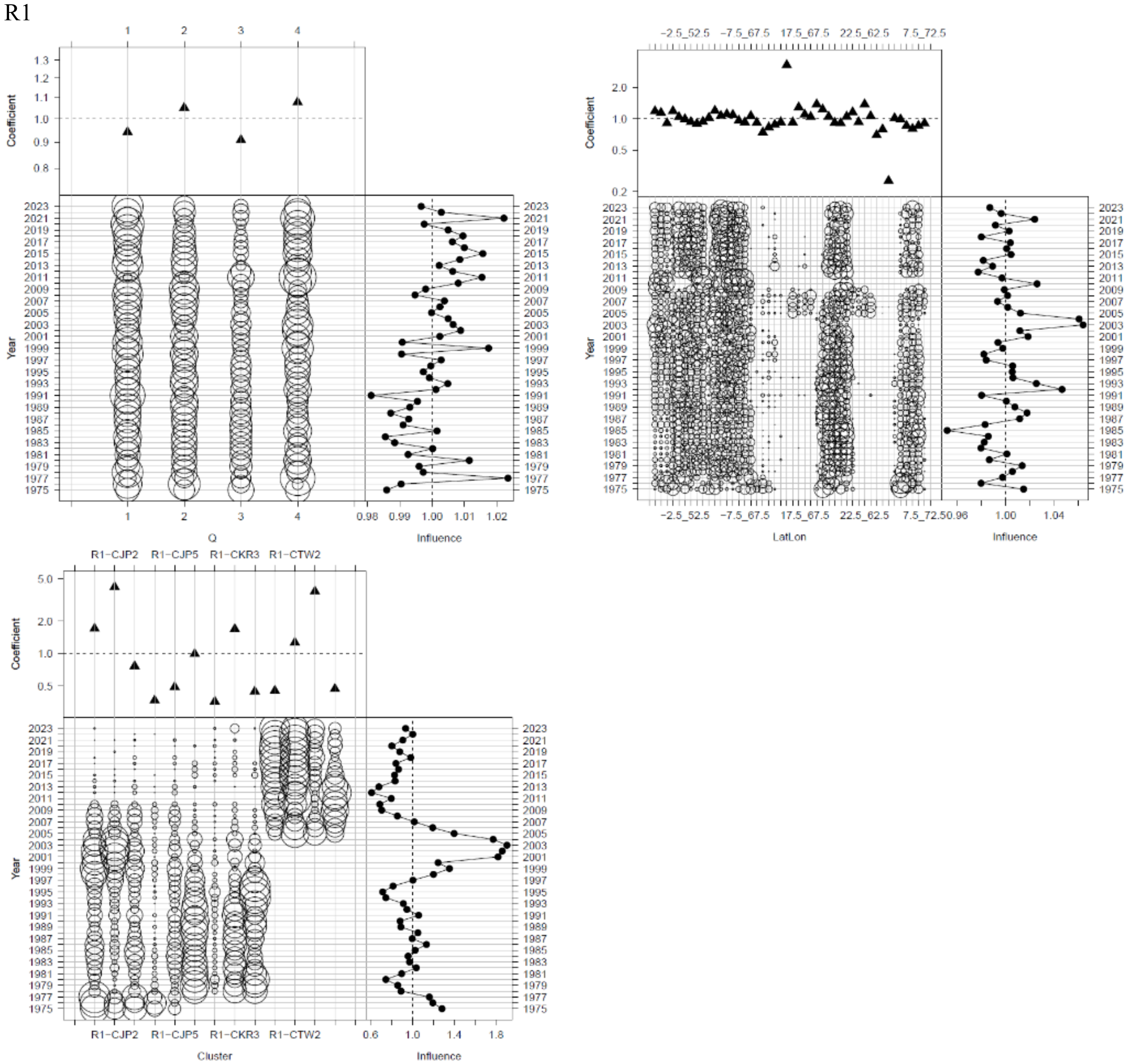


Fig. 12. Influence plot for CPUE standardization for yellowfin (4 area model, annual).

R2

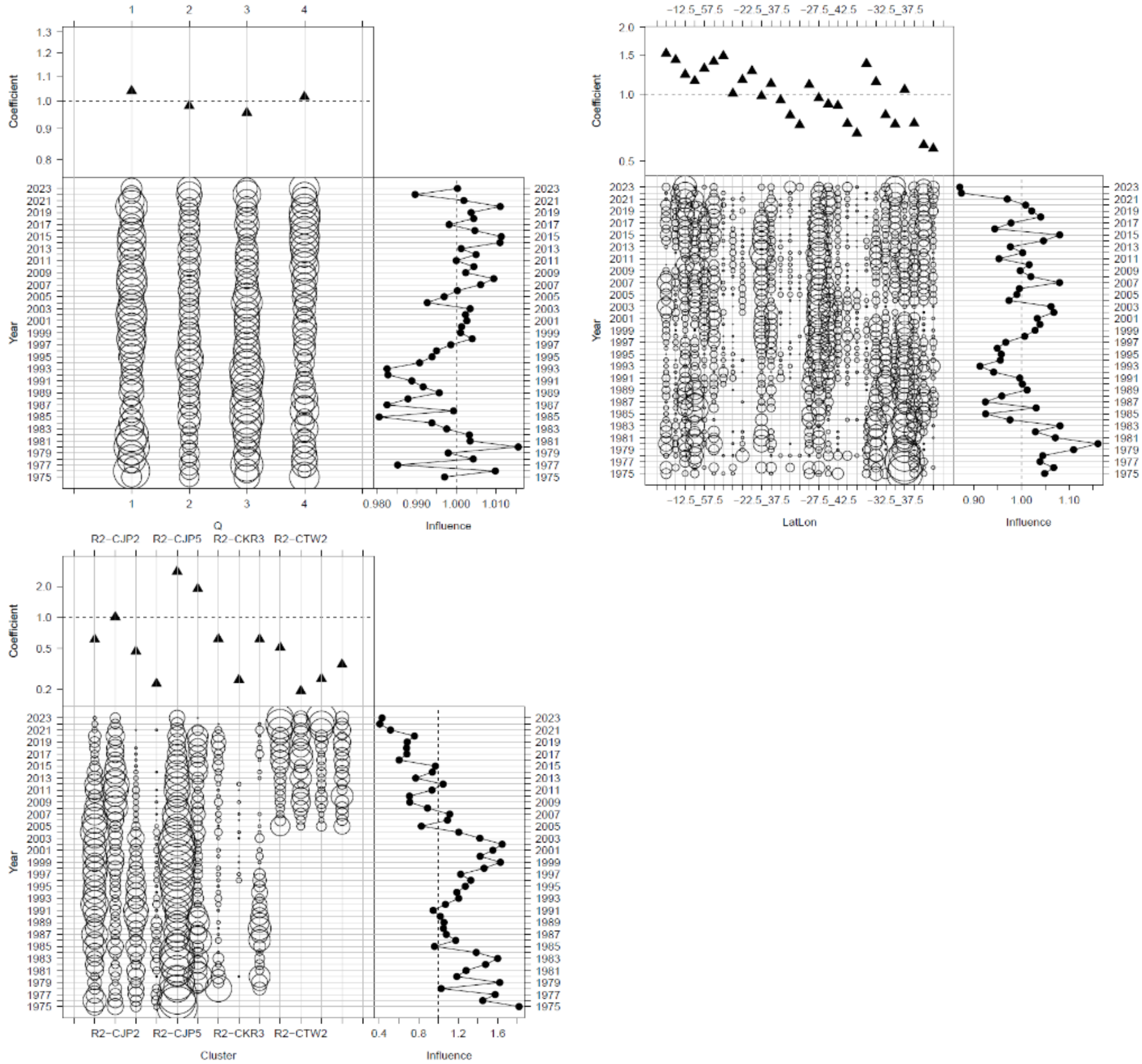


Fig. 12. Influence plot for CPUE standardization for yellowfin (4 area model, annual). **(continued)**

R3

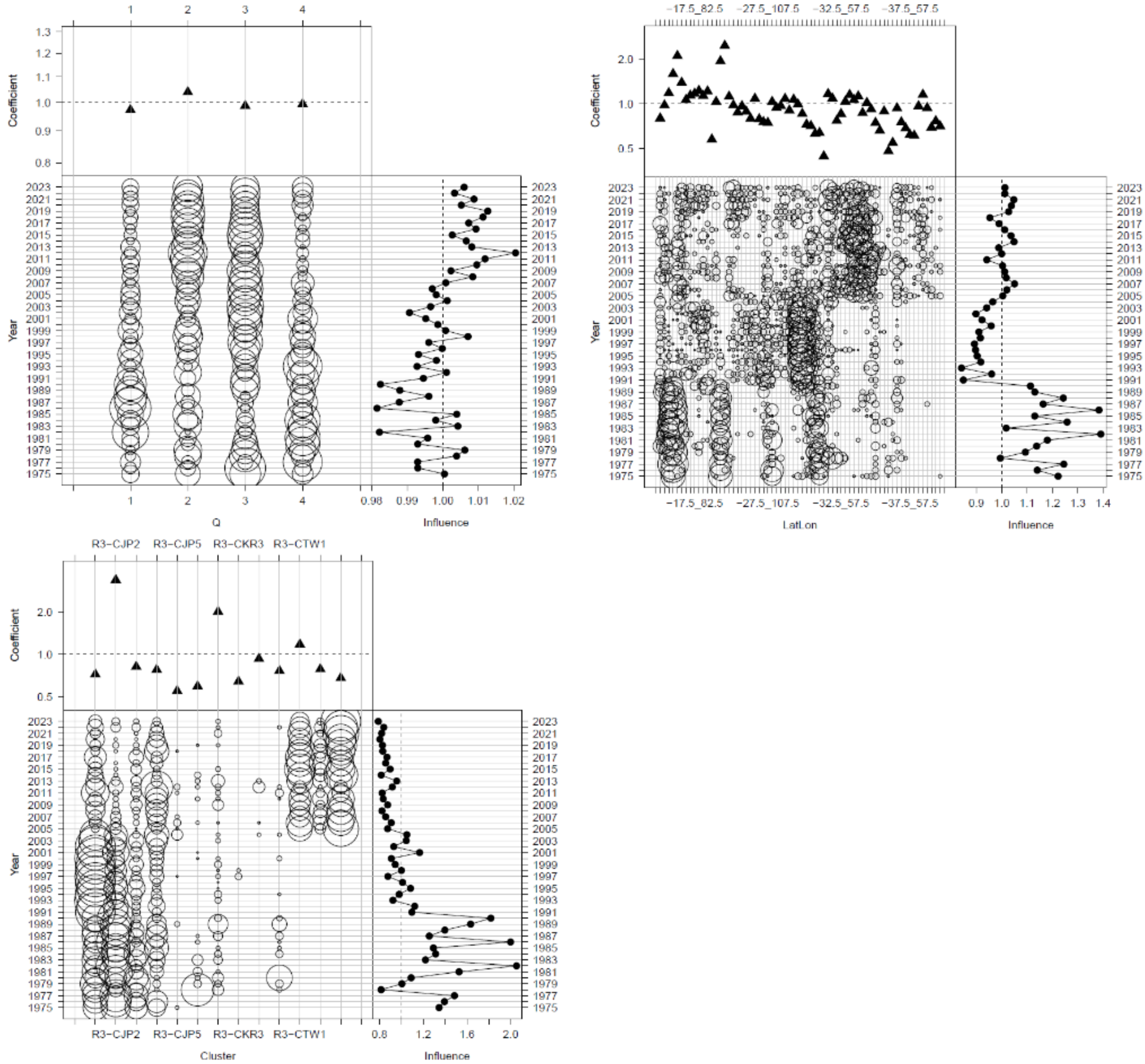


Fig. 12. Influence plot for CPUE standardization for yellowfin (4 area model, annual). **(continued)**

R4

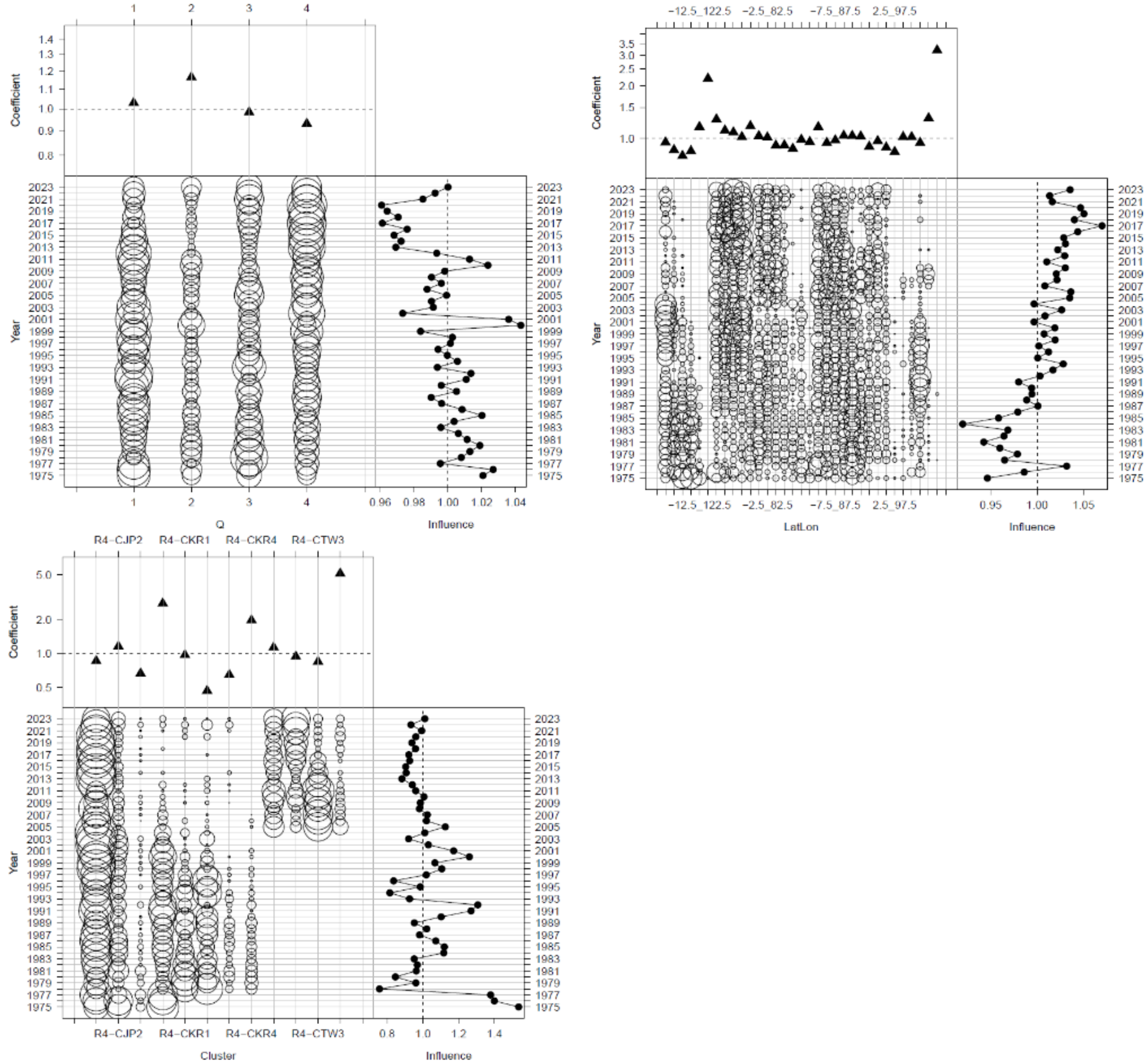


Fig. 12. Influence plot for CPUE standardization for yellowfin (4 area model, annual). **(continued)**

R1

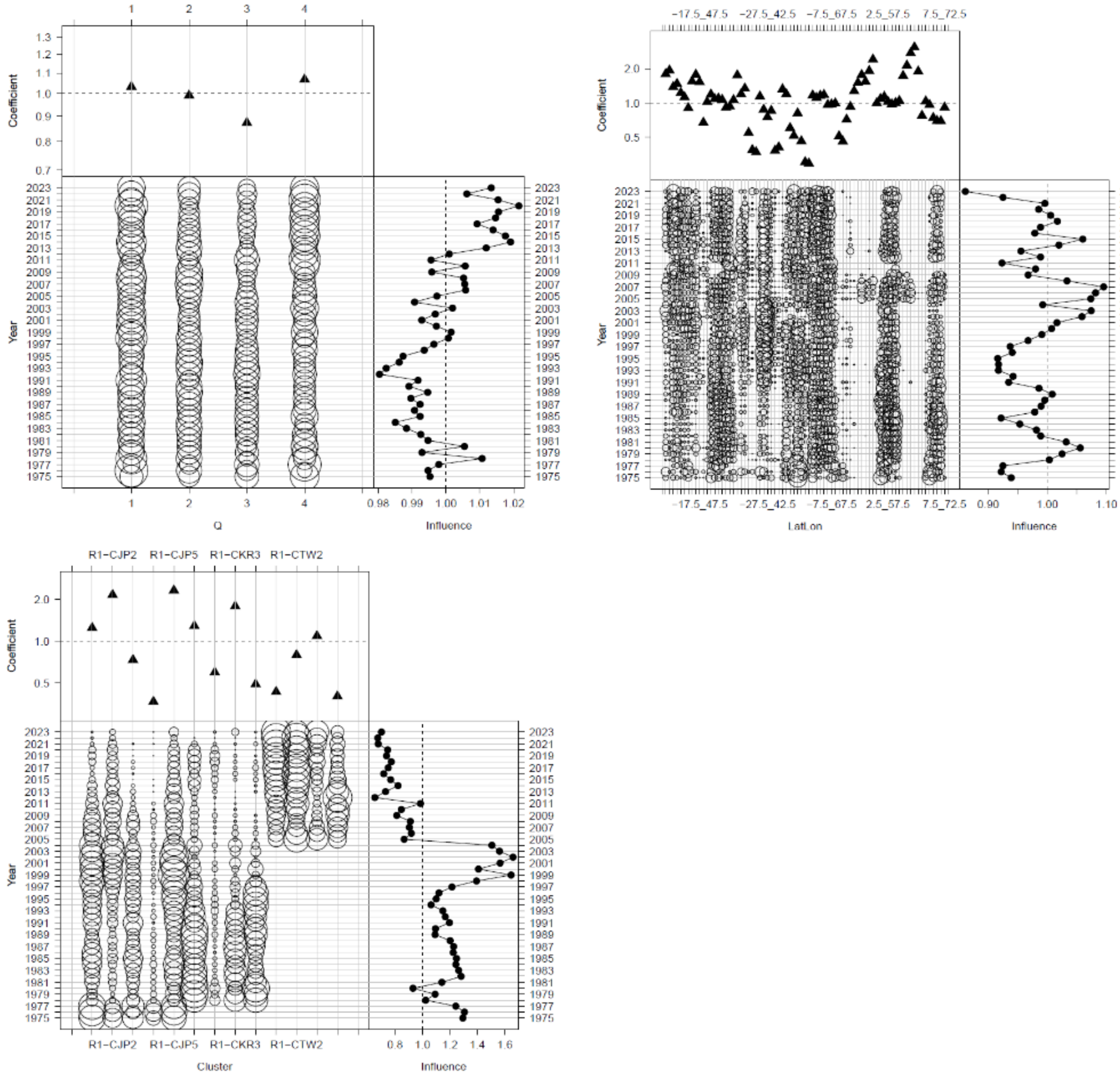


Fig. 13. Influence plot for CPUE standardization for yellowfin (2 area (R1+R2 and R3+R4), annual).

R2

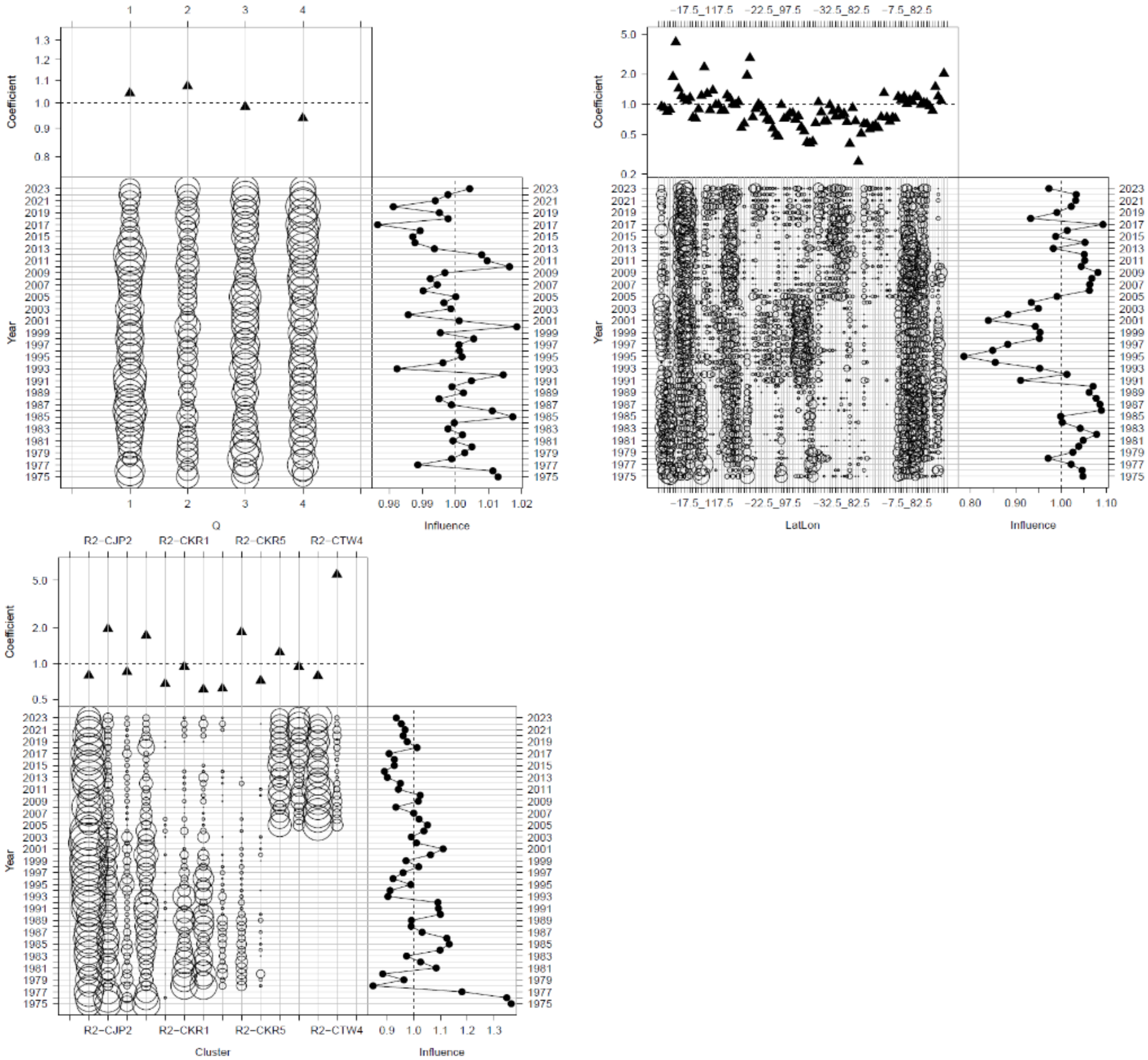


Fig. 13. Influence plot for CPUE standardization for yellowfin (2 area (R1+R2 and R3+R4), annual).
(continued)

R1

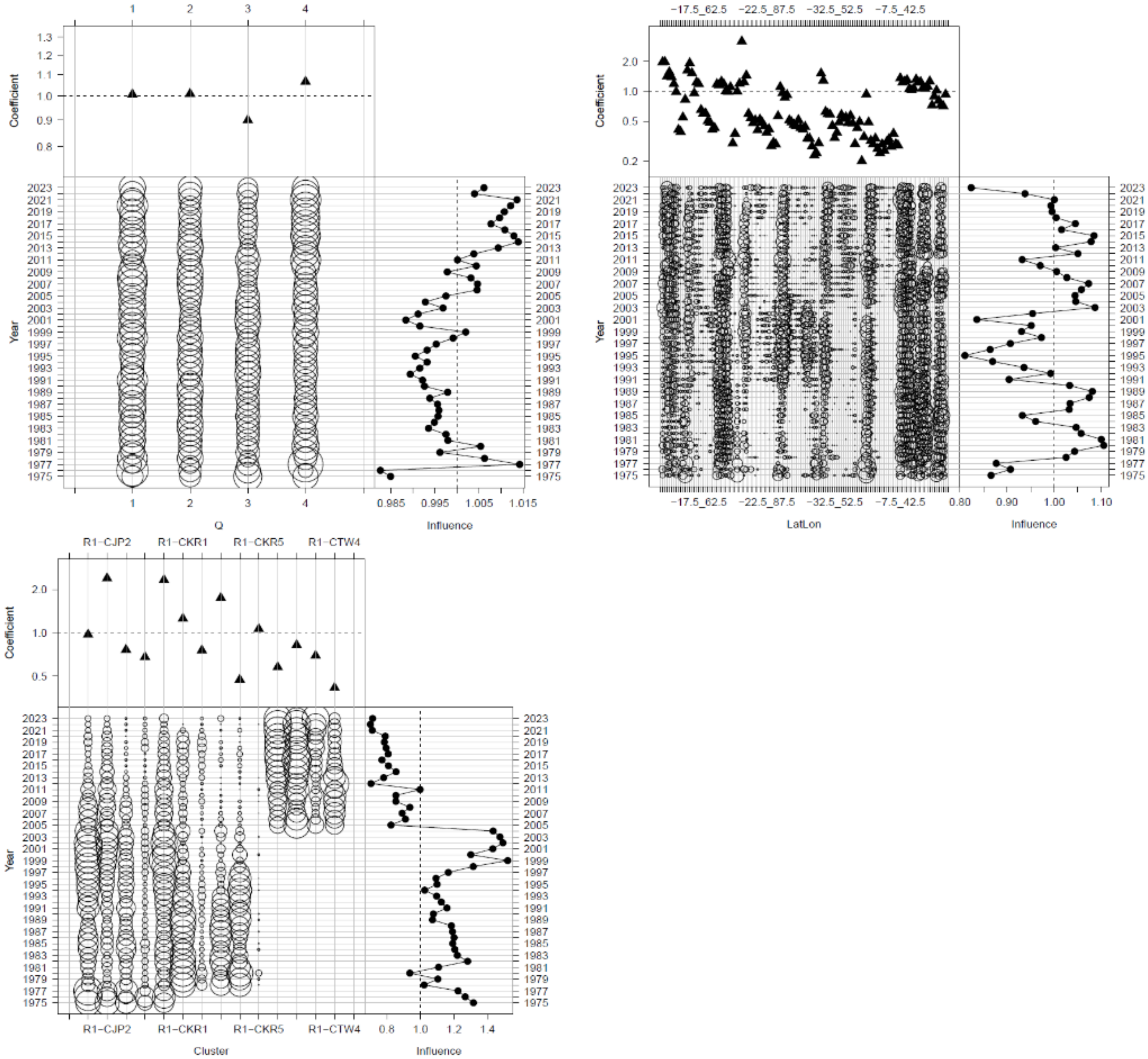


Fig. 14. Influence plot for CPUE standardization for yellowfin (2 area (R1+R2+ R3 and R4), annual).

R2

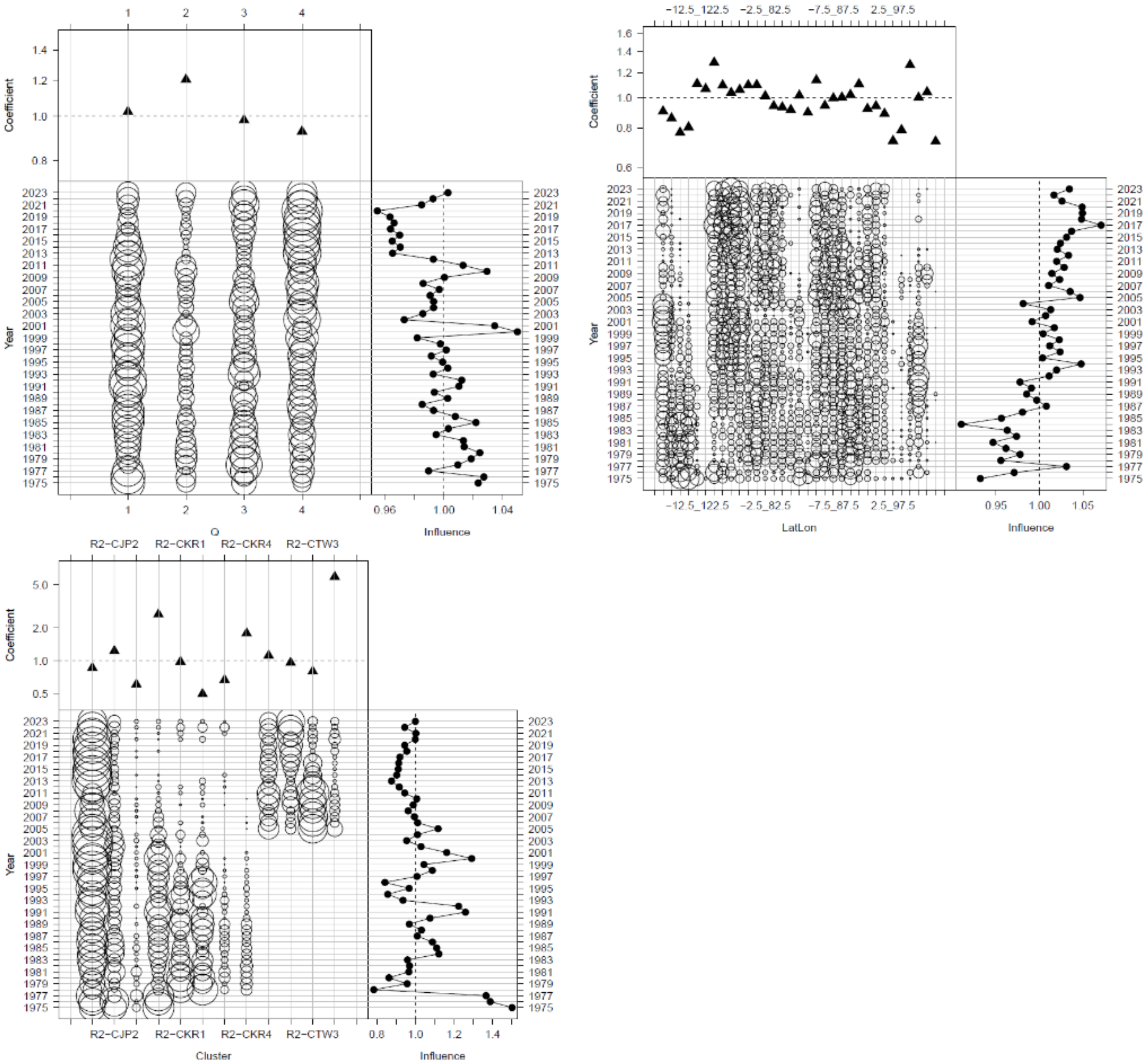


Fig. 14. Influence plot for CPUE standardization for yellowfin (2 area (R1+R2+ R3 and R4), annual).**(continued)**