Joint CPUE indices for the albacore *Thunnus alalunga* in the Indian Ocean based on Japanese, Korean and Taiwanese longline fisheries data

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ABSTRACT

Joint CPUE standardization was conducted for the Indian Ocean albacore tuna based on Japanese, Korean and Taiwanese longline fisheries data up to 2020 to provide the WPTmT with information on abundance indices for use in the coming stock assessment for this stock. The intention was to produce reliable indices by increasing the spatial and temporal coverage of fishery data. Due to the limitation of remote data access, an approach adopted among the three counties for the previous analyses of tropical tunas for IOTC and ICCAT was used to share only aggregated data. As an underlying analysis, a clustering approach was applied to account for the inter-annual changes of the target in each fishery in each region. For this purpose, a hierarchical clustering method with "fastcluster" was used, and the outputs of the finalized cluster were then used to assign the cluster label on fishery target to each catch-effort data. For standardizing the catch-per-unit-effort data, the conventional linear models and delta-lognormal linear models were employed for the shared aggregated data of monthly and 1° grid resolution in each region. The models were diagnosed by the standard residual plots and influence analysis.

INTRODUCTION

Tuna-RFMOs, including the IOTC, recommended that the joint CPUE of longline fisheries be developed to improve the stock assessments for tropical tunas, and thus the IOTC has conducted collaborative works for several years to produce an abundance index by combining CPUEs data from major longline fleets. An ensemble approach of fishery data from multiple longline fleets has been applied to the tropical and temperate tuna species for their stock assessments (e.g. Hoyle et al. 2018, Hoyle et al. 2019a, 2019b, Kitakado et al. 2021a, 2021b).

Following these customary practices used in the IOTC and other RFMOs, we conducted a collaborative study for developing the abundance indices for the Indian Ocean albacore tuna based on Japanese, Korean and Taiwanese longline fisheries data up to 2020 for use in the coming stock assessment for this stock.

MATERIALS

Data sharing protocol

Under the pandemic circumstance, a data sharing protocol among the three countries adopted for the previous analyses of tropical tunas for IOTC and ICCAT was used with a restriction of data access only by the Chair of the group (Toshihide Kitakado) for reduced resolution of data set (not operational data but some aggregated data over 1° square grid by month by vessel). The data set combined for albacore CPUE standardization were available from 1975 to 2020, with data fields of year and month of operation, location to 1° of latitude and longitude, vessel id, number of hooks, and catch by species in number. We classified the species into albacore (ALB), bigeye (BET), yellowfin (YFT), southern bluefin tuna (SBT), black marlin (BLM), blue marlin (BUM), swordfish (SWO), other billfishes (BIL), sharks (SKX) and others (OTH).

The data period from the three countries are as follows:

Japan: 1975-2020

Korea: 1979-2020

Taiwan: 2005-2020

Figure 1 shows the definition of regions used in the analysis. Figure 2 provides a figure comparing the temporal coverage and similarities/dissimilarities of nominal CPUEs among fisheries data in each region. More detailed information on fisheries data especially spatial coverage can be seen in a document of each country (Matsumoto 2022; Lee et al. 2022; Wang et al. 2022).

Proportion of zero data

Figure 3 provides the time series of positive catch proportions of each fishery data in each region. Except for very recent years in Region 4 in Taiwanese data, the proportion of zero catch tends not to be small.

METHODS

For clustering analyses to account for the change in target, the data were aggregated by 10-days duration (1st-10th, 11th-20th, and 21st~ for each month) based on the agreement in the data sharing protocol of the trilateral collaborative working group. The number of clusters was determined when the relative improvement of SS within-clusters was less than 10%. See some details shown in Wang et al. (2021). Also, the results of clustering are given in Matsumoto (2022), Lee et al. (2022) and Wang et al. (2022).

For standardizing the catch-per-unit-effort data, the conventional linear models and delta-lognormal linear models were employed for data of monthly and 1° grid resolution in each region. Considering relatively high zero-catch proportion, we mainly used the delta-lognormal models, but some comparison with the conventional log-linear model with a constant adjustment was also used. Results based on those models were diagnosed by the standard residual plots and influence analysis. See Table 1 for the list of models with the description below.

Log-normal (LN) regression models with a constant adjustment

We used an adjustment factor (here 10% of mean of CPUE) to the CPUE data to employ conventional log-normal distributions as follows:

$$\log(CPUE + c) = Main\,effects + Interactions + Error$$

Potential covariates used in the analysis were shown below:

- Temporal component (year, quarter, year*quarter)
- Spatial component (5° squared longitudinal and latitudinal grid)
- Vessel ID
- Cluster category
- Interactions between the spatial component and quarter

The error terms are assumed to be independently and identically distributed as the normal distribution with mean 0 and standard deviation σ. The constant adjustment factor, *c*, is 10% of the overall mean as has been used in previous analyses.

Delta-lognormal (DL) regression model

A delta-lognormal model was also tested to account for “zero data” statistically as has been used in previous analyses (see e.g. Hoyle et al. 2018). For the first component of “zero” or “non-zero” is expressed as a binomial distribution with a probability of “non-zero” catch as a logistic relationship with some explanatory variables, and the second component for positive catch assumed the same regression structures used in the LN regression models with a constant adjustment. The logarithm of the number of hooks was also used in the delta-component of analysis.

Diagnostics and impacts of covariates (Residual plots, Q-Q plots, influence plots)

The standard residual plots were for the diagnosis for fitting of models to the data and Q-Q plots (only for the positive catch component in DL models). In addition, we used influence plots (Bentley et al. 2012) to interpret the contribution of each covariate to the difference between nominal and standardized temporal effects.

Extracts of abundance indices from models with interactions

Once the model fitting and model evaluation were conducted, the final output of the abundance index is extracted through an exercise of the least square means (so-called LS means) to account for heterogeneity of amount of data over covariate categories (as well as the standardized probability of "non-zero" catches in DL models).

RESULTS

Full evaluation of models thought the model selection criterion has not yet reached, but comparison of results over the following models are shown in Figure 4. Also, the diagnostics and influence plots were shown in Figure 5.

General and specific observations are given below:

- For Regions 1-3, the most stable series was generate by model “c1v0e1r0_c1v1r1”, which considered the effects of target and number of efforts in the delta-component and all the effects including the quarter-space interactions in the positive lognormal component.
- The same model was used for Region 4, but as the estimates were instable, the log-normal model was used an alternative approach. However, the diagnostics plots shows some deviation from the normal distribution. Therefore, other methods could be considered, such as picking up data from a specific quarter, using data only for albacore targets, or using results for each fishery.
- Although not an exact match, the selected std-CPUE series in this paper generally showed a similar pattern to the CPUE previously used in the 2019 assessment, as shown in the superimposed figures in Figure xx. However, some more careful examinations might be needed for understanding the recent increasing trend in Region 4.
- There was reasonable consistency between the cluster information and the estimated coefficients of the target effect.

Caveats:

- The current use of aggregated data means that if there is at least one operation in each data grid (1° grid resolution) for each month of each year in each cluster, all three fisheries' data will be equally weighted in the likelihood. However, the degree of information may vary depending on the actual number of operations. This is one of the disadvantages in analysis with aggregated data.
- As the analysis was carried out using data up to 2020, there is again a time lag of two years between the most recent year in the data and the year of assessment.

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Table 1. The list of models used in this paper.

	Delta-component						Positive-component				
Model	YrQtr	LonLat	Target	Vessel	Ln(Effort)	Interaction	YrQtr	LonLat	Target	Vessel	Interaction
c1v1e0r0_c1v1r0	X	X	X	X			X	X	X	X	
c1v1e0r1_c1v1r1	X	X	X	X		Qtr:LonLat	X	X	X	X	Qtr:LonLat
c1v0e1r0_c1v1r1	X	X	X		X		X	X	X	X	Qtr:LonLat
c1v0e1r1_c1v0r1	X	X	X		X	Qtr:LonLat	X	X	X		Qtr:LonLat
c1v0e1r1_c1v1r1	X	X	X		X	Qtr:LonLat	X	X	X	X	Qtr:LonLat
c1v1e1r1_c1v1r1	X	X	X	X	X	Qtr:LonLat	X	X	X	X	Qtr:LonLat
c1v1r0							X	X	X	X	
c1v1r1							X	X	X	X	Qtr:LonLat

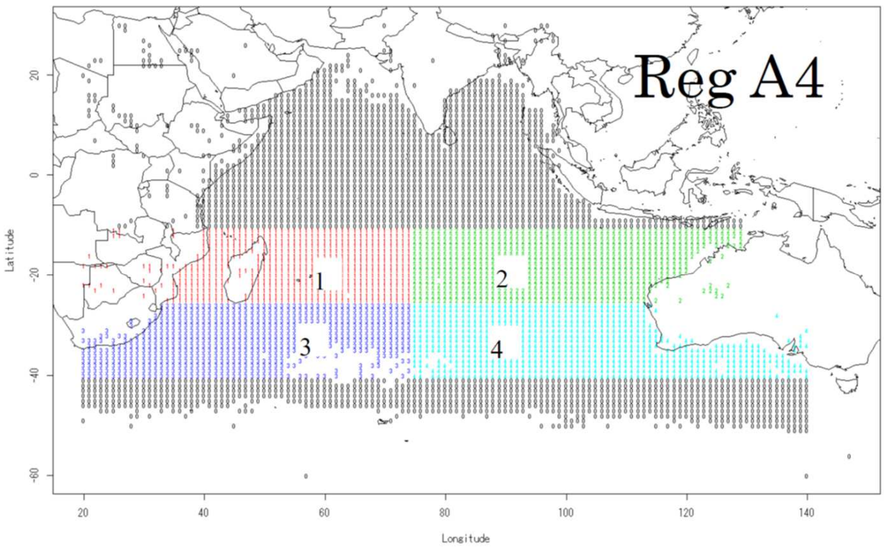


Figure 1. Definition of the regions used in the analysis.

Figure 2. Comparison of time seires among the three fisheries.

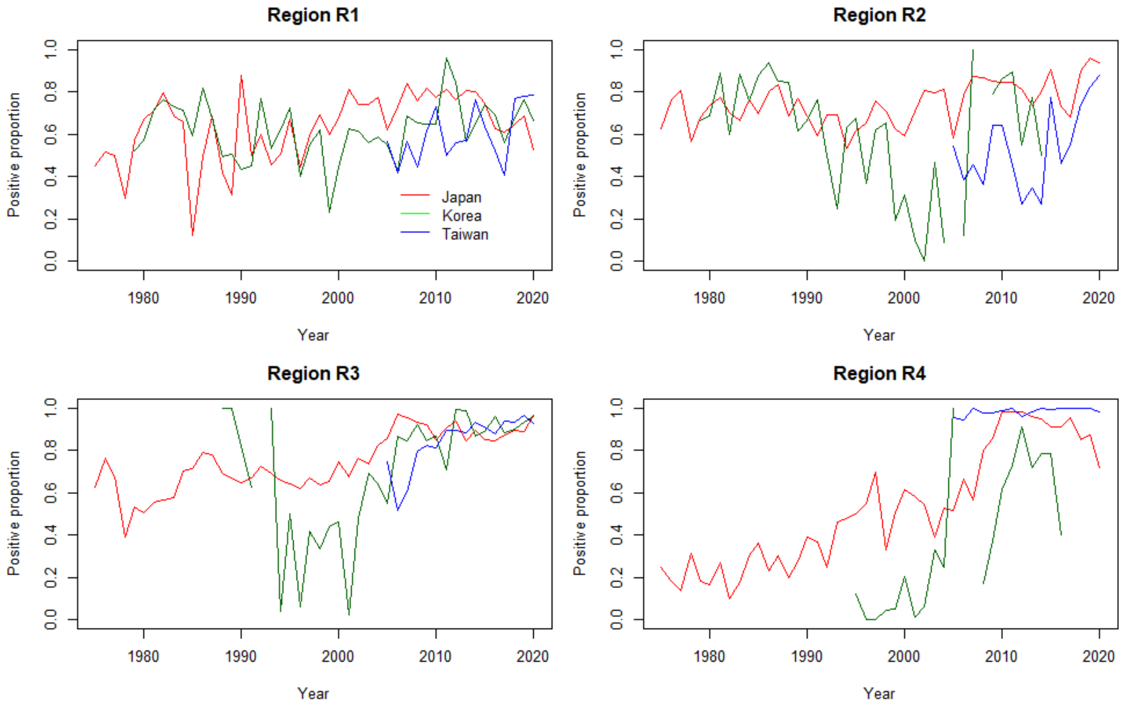


Figure 3 Time series of positive catch proportions of each fishery data in each region.

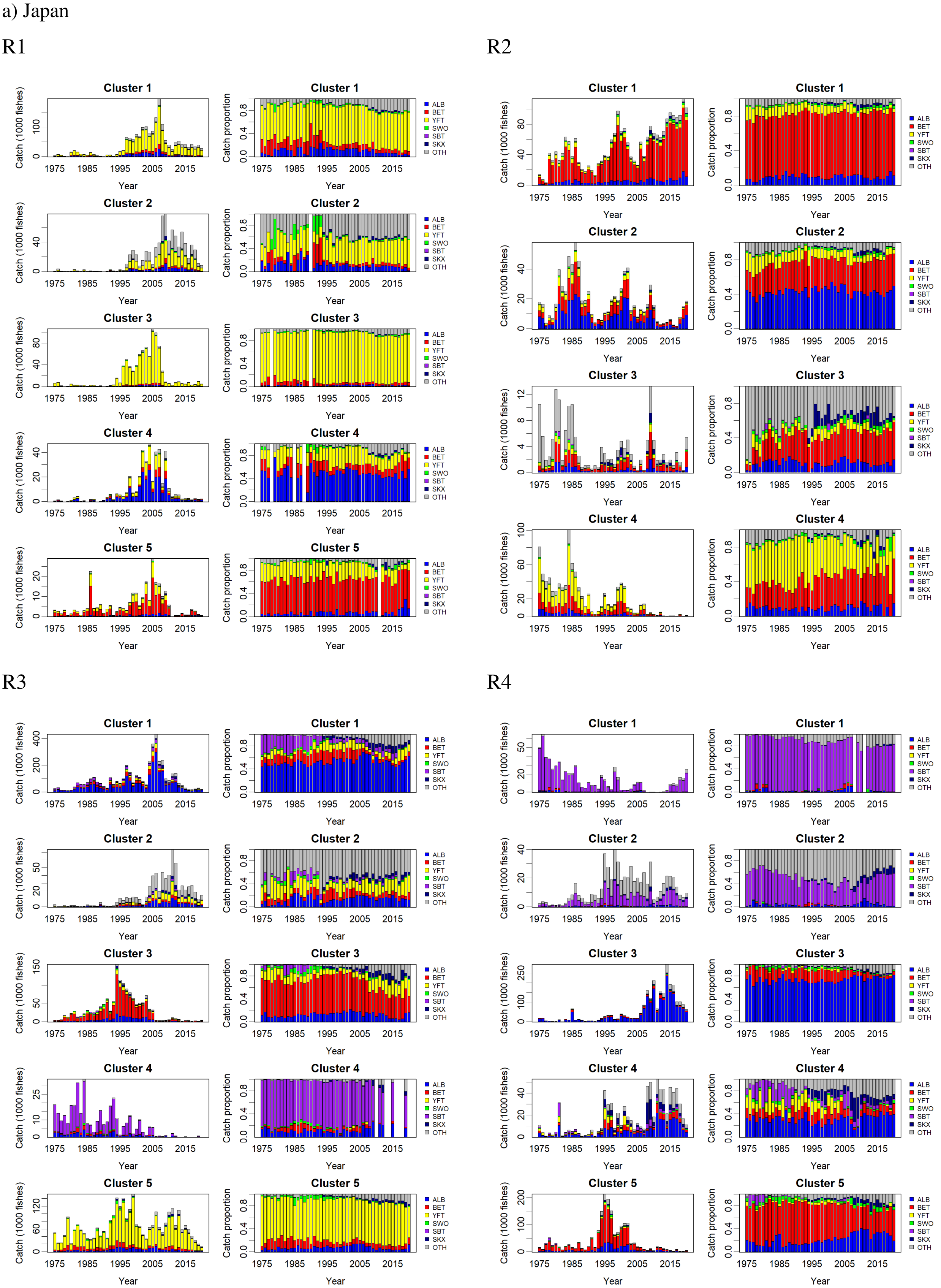


Figure 4(a): Species composition for each cluster in Japanese fisheries.

b) Korea

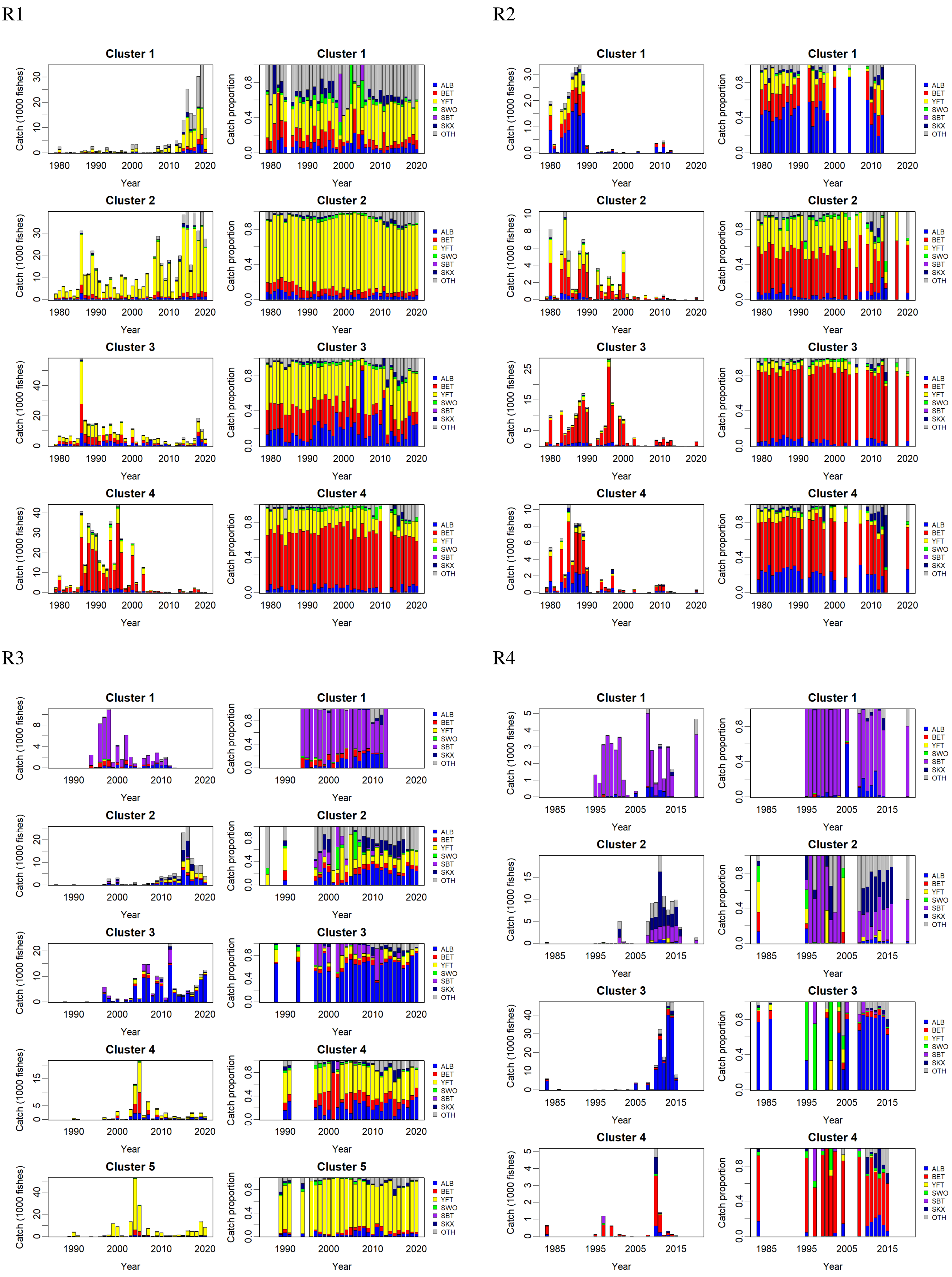
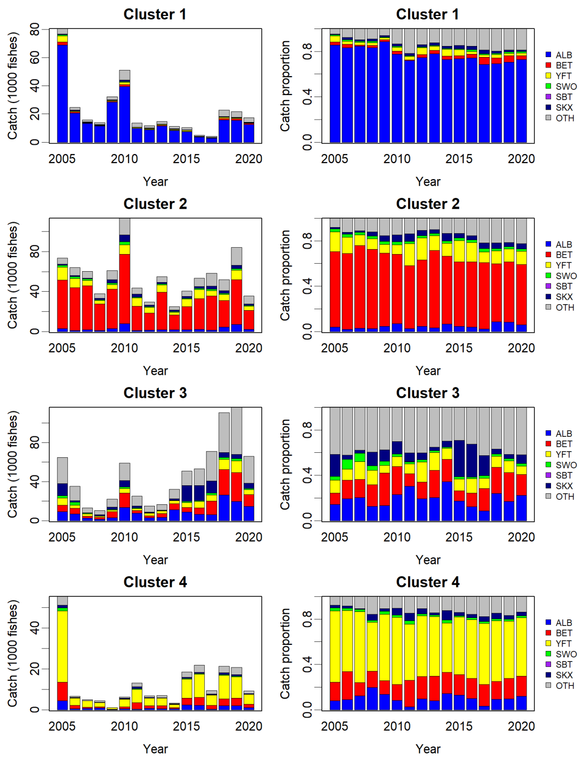


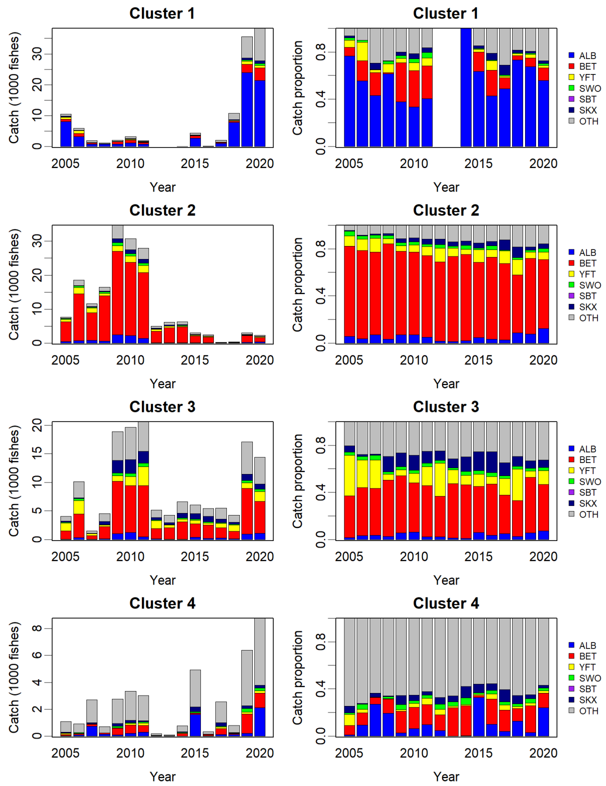
Figure 4(b): Species composition for each cluster in Korean fisheries.

c) Taiwan

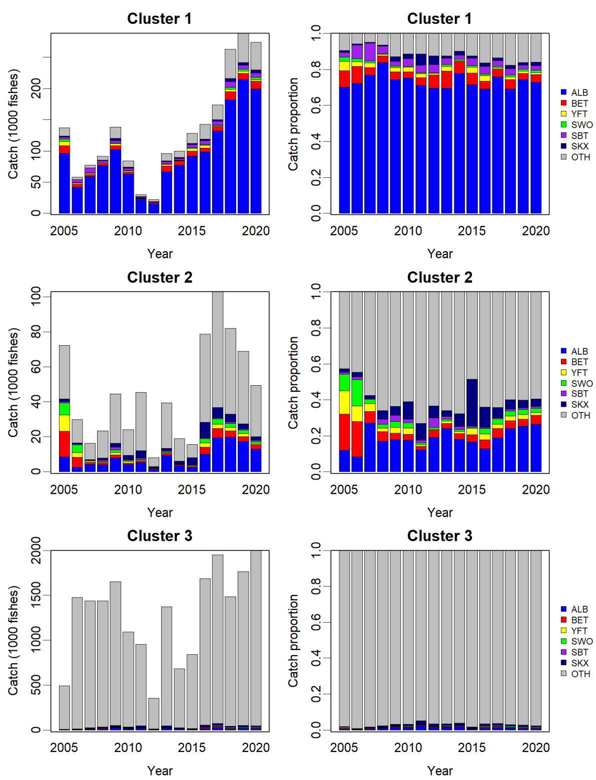
R1



R2



R3



R4

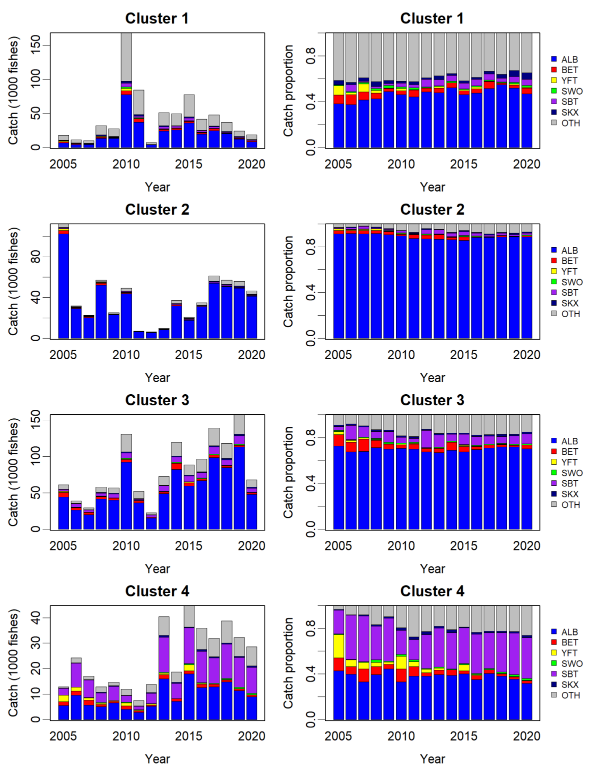


Figure 4(c): Species composition for each cluster in Taiwanese fisheries.

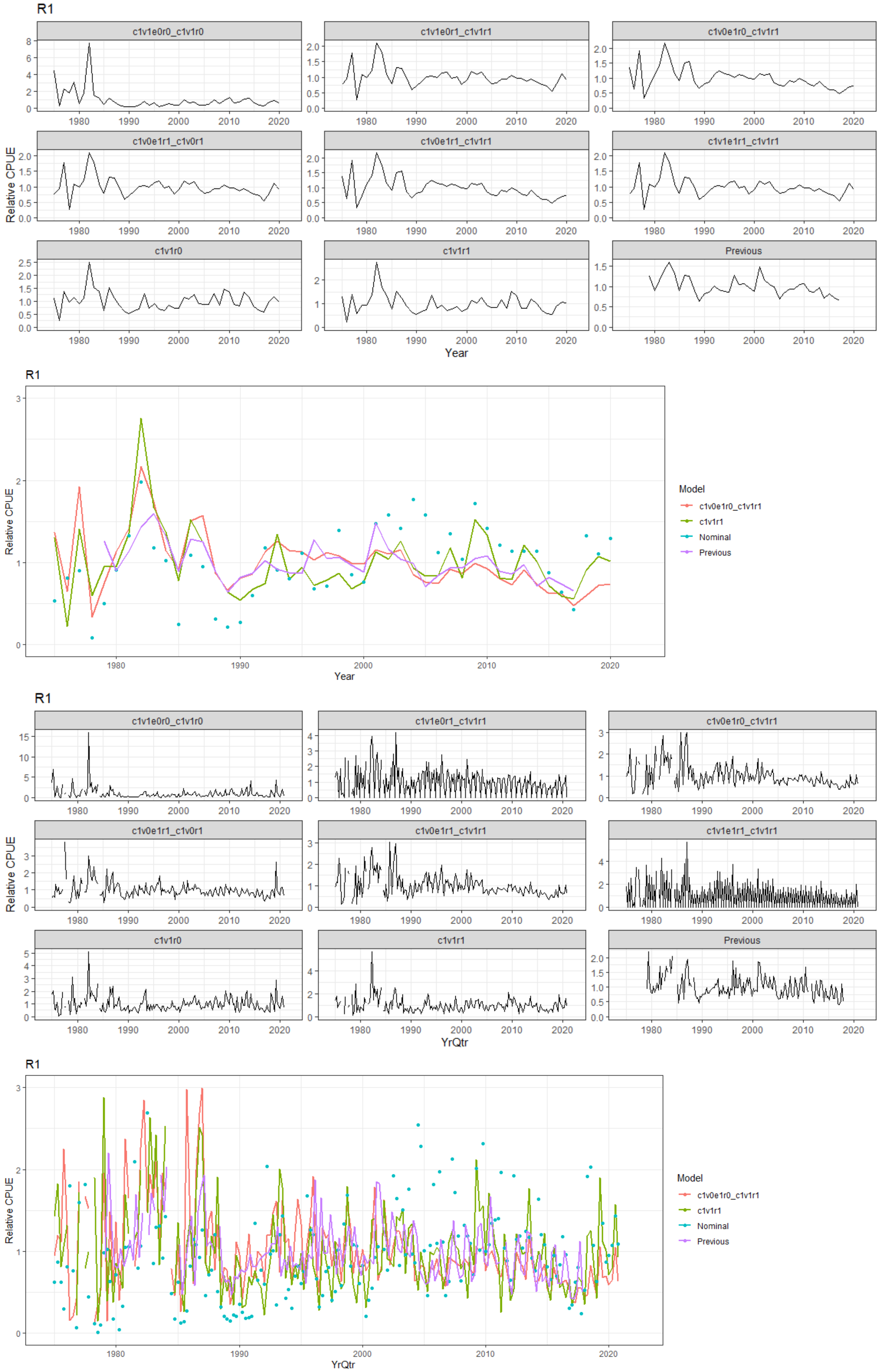


Figure 4(a). Comparison of annual (top) and quarterly (bottom) standardized CPUEs in R1.

Figure 4(b). Comparison of annual and quarterly standardized CPUEs in R2.

Figure 4(c). Comparison of annual and quarterly standardized CPUEs in R3.

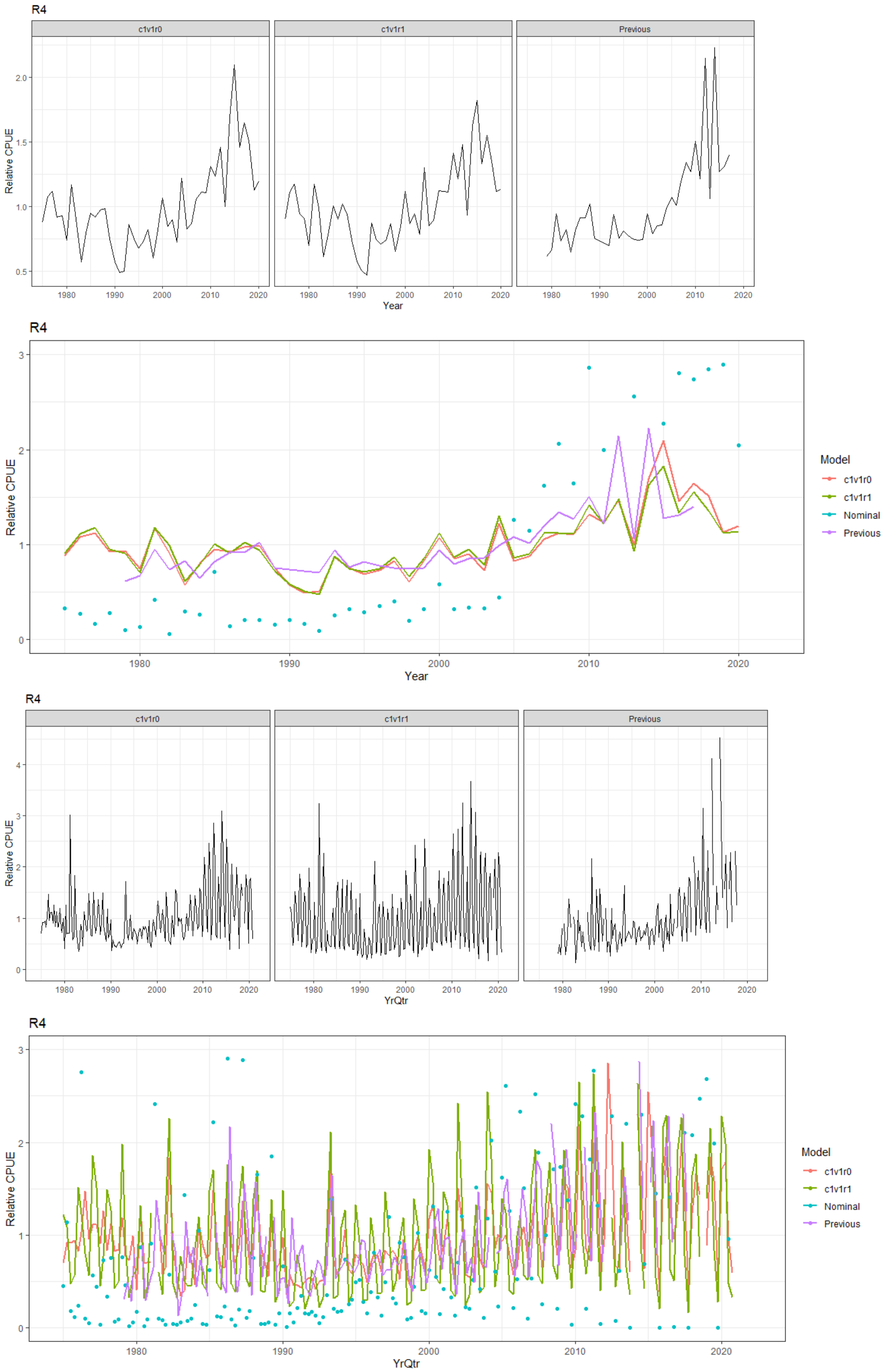
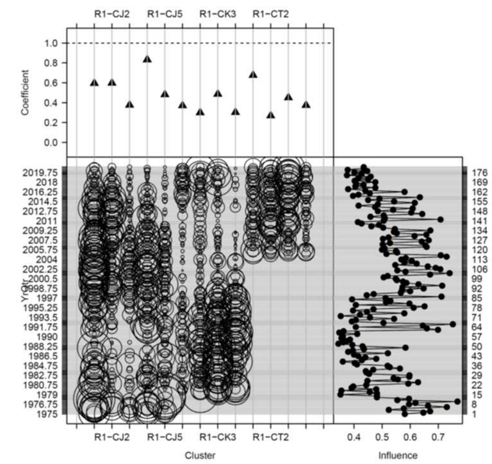


Figure 4(d). Comparison of annual and quarterly standardized CPUEs in R4.

(Delta-component)



(Lognormal-component)

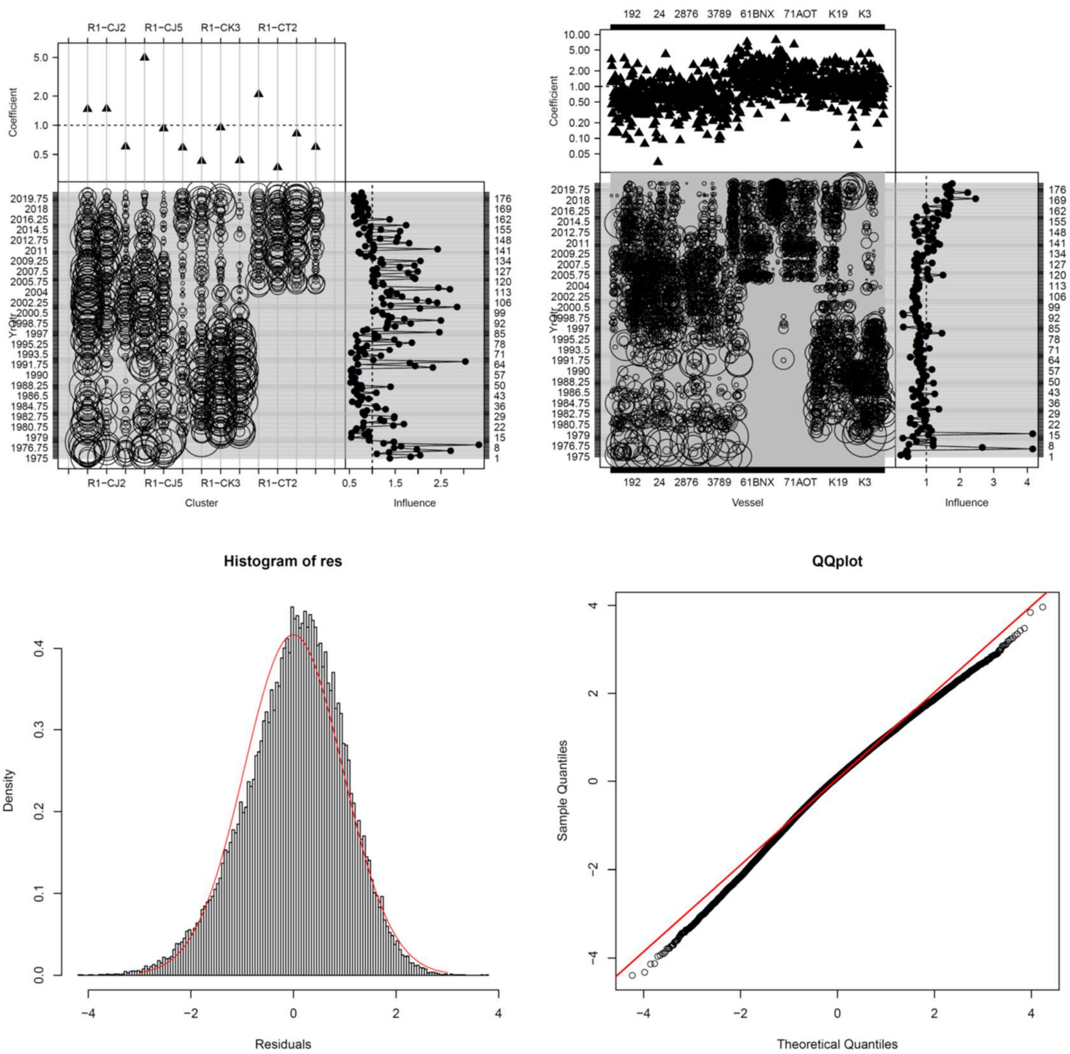
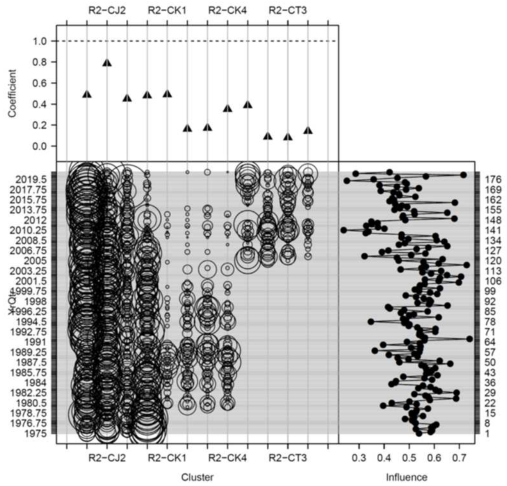


Figure 5(a). Diagnostics and influence plots for the Cluster and/or Vessel effects for Model c1v0e1r0_c1v1r1 (DL ~ YrQ + LonLat + Cluster + LnEffort ; LN~ YrQ + LonLat + Cluster + Vessel + Q*LonLat) in R1.

(Delta-component)



(Lognormal-component)

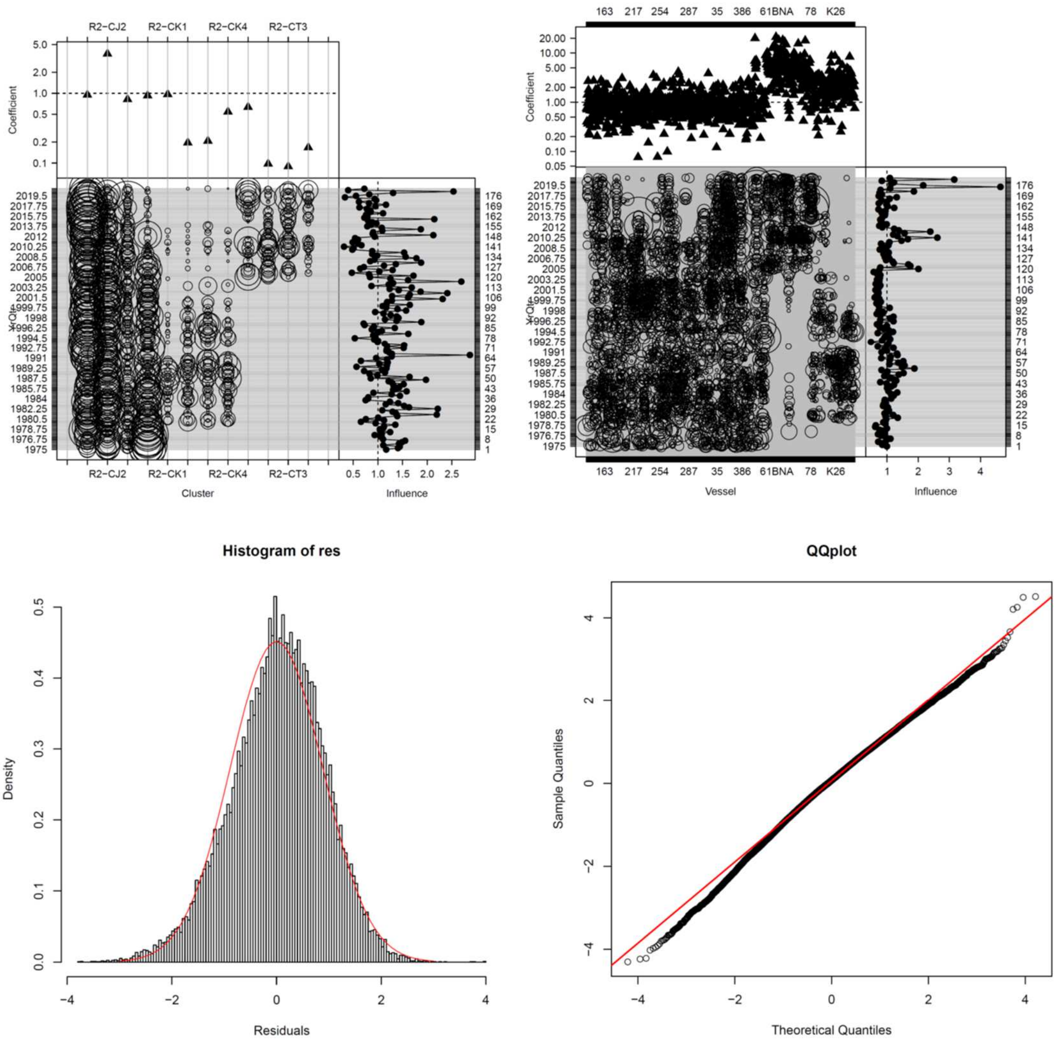
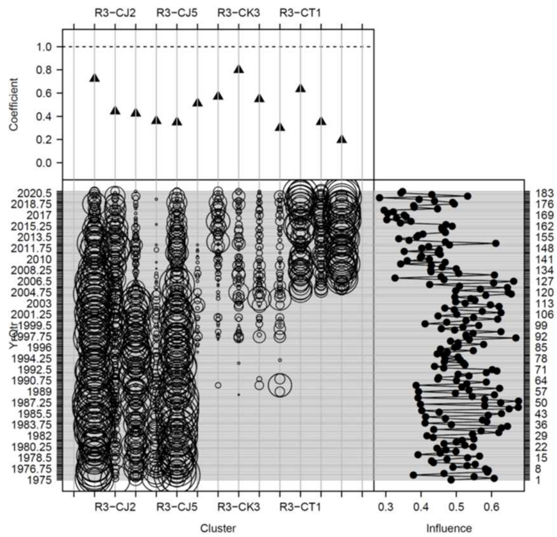
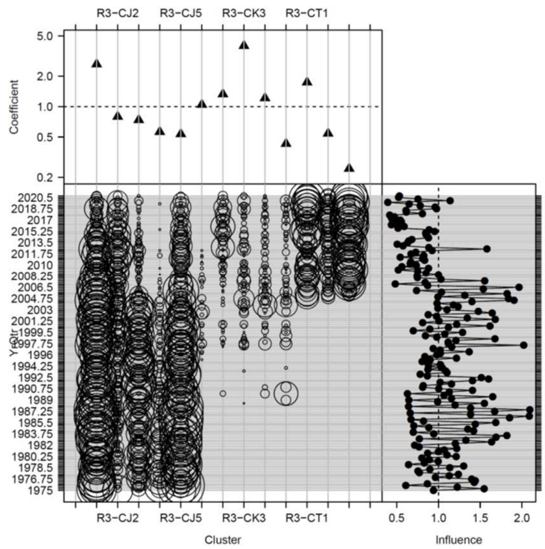


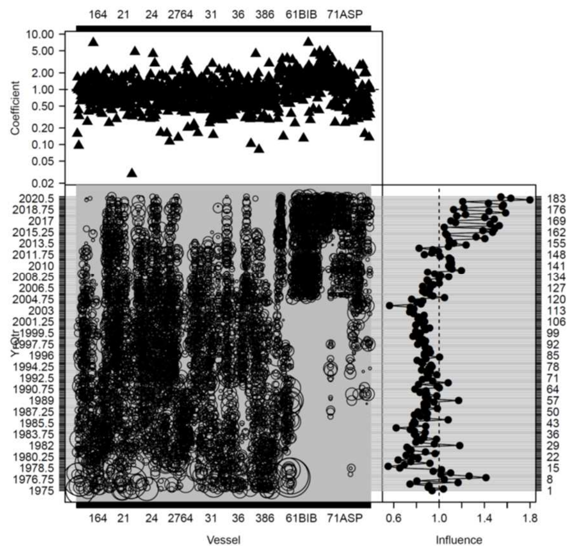
Figure 5(b). Diagnostics and influence plots for the Cluster and/or Vessel effects for Model c1v0e1r0_c1v1r1 (DL ~ YrQ + LonLat + Cluster + LnEffort ; LN~ YrQ + LonLat + Cluster + Vessel + Q*LonLat) in R2.

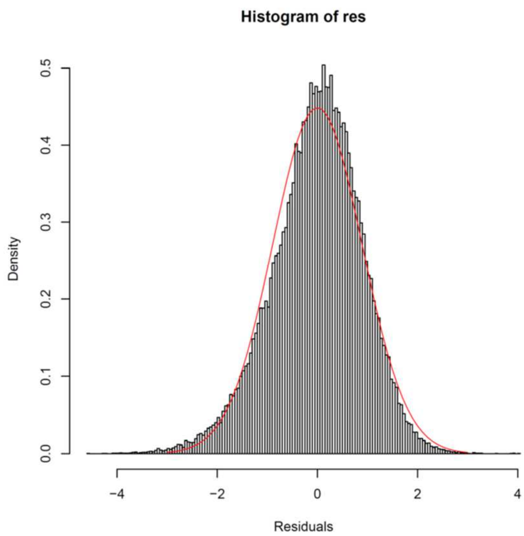
(Delta-component)



(Lognormal-component)







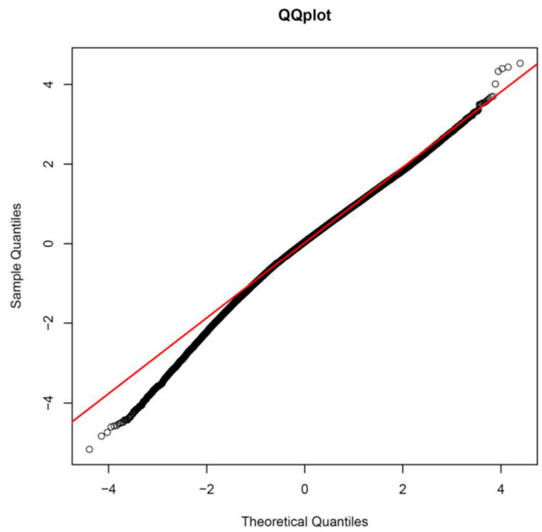


Figure 5(c). Diagnostics and influence plots for the Cluster and/or Vessel effects for Model c1v0e1r0_c1v1r1 (DL ~ YrQ + LonLat + Cluster + LnEffort; LN~ YrQ + LonLat + Cluster + Vessel + Q*LonLat) in R3.

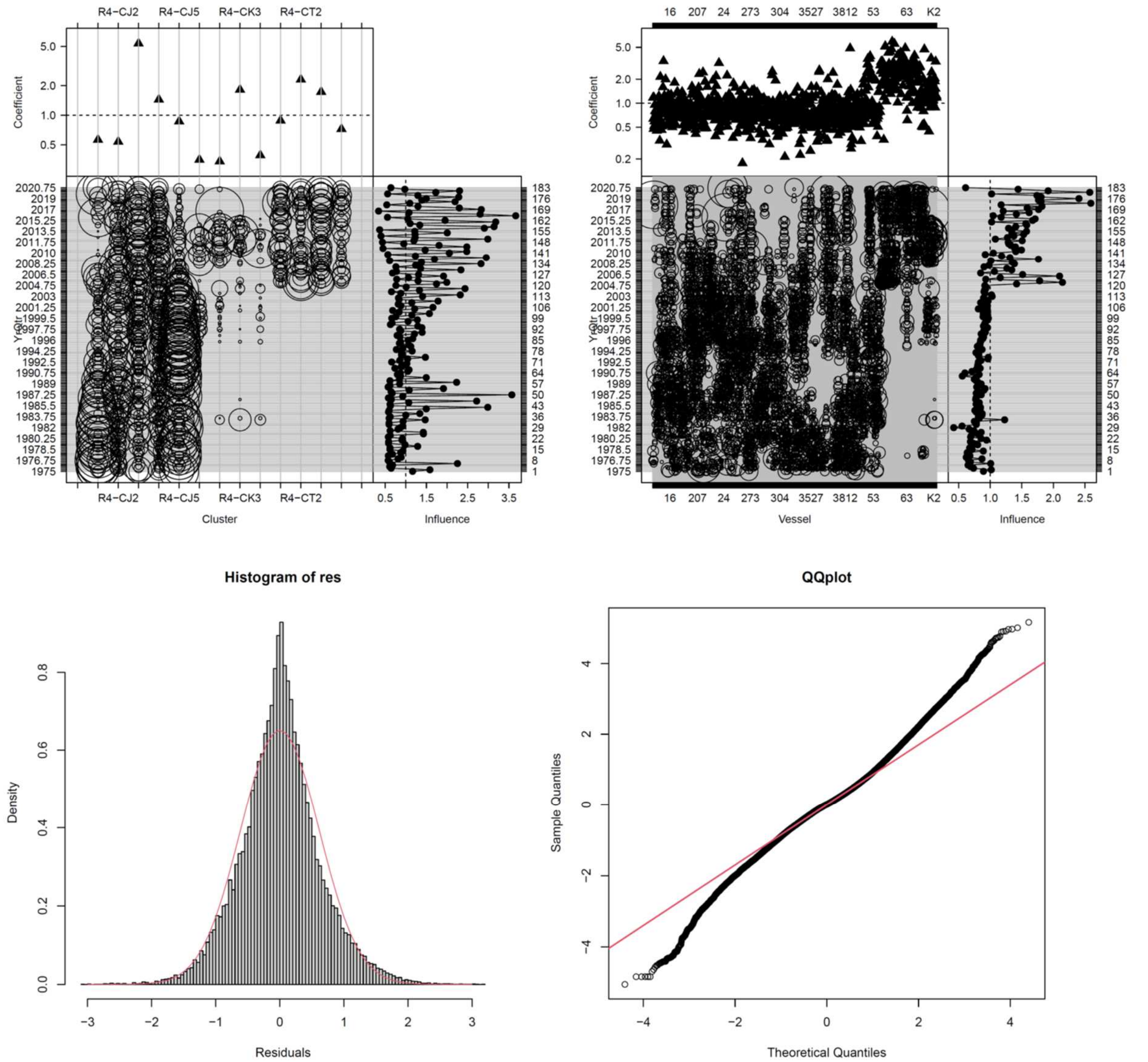


Figure 5(d). Diagnostics and influence plots for Model c1v1r1 (~ YrQ + LonLat + Cluster + Vessel+ Q*LonLat) in R4.