# CPUE standardization of albacore tuna caught by Korean tuna longline fishery in the Indian Ocean, 1979-2020

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**Abstract**

In this study the CPUE of albacore tuna caught by Korean tuna longline fishery in the Indian Ocean was standardized using lognormal constant model and delta lognormal model with added cluster factor as a categorical variable for addressing target changes over time. The data used for the CPUE standardization were catch in number, hooks used, fishing location (5° cell), and vessel identifier by year, quarter, and region. The standardized CPUE in the western subtropical region (R1) decreased from the early 1980s to the early 1990s, after that showed at low level with a fluctuation, and has increased since the 2010s. In the western temperate region (R3), since the early 2000s it has shown an increasing trend. However, we could not estimate the recent trend of the indices for the eastern subtropical region (R2) and the eastern temperate region (R4), because there was no fishing information or missing data.

## Introduction

Albacore tuna is one of major important commercial species of Korean tuna longline fishery in the Indian Ocean. Albacore tuna catch had considerably increased from the mid-1960s and peaked at about 10 thousand tons in 1974, but sharply decreased to below 100 tons thereafter. After 2009 it increased and showed over 600 tons in 2013 and 2014, but again decreased in 2016 (Lee et al. 2019, Lee et al. 2021). This document provides results of CPUE (catch per unit effort) standardization of albacore tuna caught by Korean tuna longline fishery in the Indian Ocean as well as clustering analysis for addressing target changes over time using methods developed by a trilateral collaborative study (Kitakado et al. 2021).

## Data and Method

Catch and effort data used in this study were collected from logbooks filled out by captains onboard. The data were plotted to explore changes in geographical distributions of efforts and albacore catch of Korean tuna longline fishery in the Indian Ocean.

To address target changes over time, a clustering approach was used as in the previous study (Hoyle et al. 2019) and the method is described in detail in Kitakado et al. (2021). Data used for clustering analysis contain vessel identifier (id), operation date, operation location to 1°, number of hooks and floats, and catch by species in number for 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). Data are available from 1979 to 2020 because data prior to 1979 have little information of vessel id.

The CPUE of albacore tuna was standardized using lognormal constant model and delta lognormal model, and the details are described in Kitakado et al. (2021). The lognormal constant model is as follows.

$$ln(CPUE + c) \sim Year + Quarter + LatLon + Cluster + Vessel + Error$$

The definition of region for albacore CPUE is based on the current regional structure used for ALB stock assessment (R1-R4). However, the CPUE standardization for R4 could not be carried out because there were not enough data to run it.

**Results and Discussion**

Figs. 1 and 2 show geographical distributions of fishing efforts (number of hooks used) and albacore catch (in number) of Korean tuna longline fishery by decade from 1970s to 2020s in the Indian Ocean. The fishing efforts were concentrated in tropical areas between 10°N-15°S of the western Indian Ocean during the 1970s to 1990s, which targeted BET and YFT along with some ALB. Until the 1980s there was a little fishing effort in the south of 25°S, but since the 1990s some fishing vessels moved southward to fish for SBT in the western and eastern Indian Oceans around 35°S-45°S. In the 2010s, most of the fishing vessels were operated in the south of the equator and they operated mainly in the south of 20°S in the western and eastern Indian Oceans to fish for YFT, BET, SBT and sometimes ALB.

Regarding Korean tuna longline fishery, four to five clusters were chosen in each region to address target strategies (4 clusters for R1; 4 clusters for R2; 5 clusters for R3; 4 clusters for R4).

In region R1, all clusters except for cluster 1 were dominant before 2010. Cluster 2 was apparent in the first half of the year, clusters 3 and 4 in the second half of the year, and cluster 1 was more prominent in the second half of the year. Hooks used were similar in all clusters, with clusters 2 and 4 higher. Clusters 1 and 2 were formed in the southeast area, and clusters 3 and 4 in the northwest area (Fig. 3(A)). The species composition of cluster 1 showed higher YFT along with OTH, and cluster 2 was dominated by YFT. Cluster 3 had higher ALB along with similar amounts of BET and YFT, and cluster 4 was dominated by BET (Figs. 4(A) and 5(A)).

In region R2, there were a few differences in the time series among clusters, and hooks were similar in all clusters as well. Clusters 1 and 4 were formed in the western area, and clusters 2 and 3 in the eastern area (Fig. 3(B)). The species composition of cluster 1 had more ALB along with BET and YFT, cluster 2 had similar amounts of BET and YFT, cluster 3 was dominated by BET, and cluster 4 was dominated by BET, followed by ALB (Figs. 4(B) and 5(B))

In region R3, all clusters except for cluster 1 occurred since the 2000s, and clusters 1 and 3 were more prominent in the second half of the year. Hooks were similar in all clusters, with clusters 1 and 5 higher (Fig. 3(C)). Clusters 2 and 4 were formed in the north area, compared to other clusters. The species composition of cluster 1 was comprised of mostly SBT along with a few BET, cluster 2 higher OTH along with similar amounts of ALB and YFT, and cluster 3 was dominated by ALB. Cluster 4 was dominated by YFT, followed by BET and ALB, and cluster 5 was dominated by YFT (Figs. 4(C) and 5(C)).

In region R4, all clusters were apparent in the middle or late of the period and in the middle or the second half of the year. Hooks were similar in all clusters. There is no difference in longitude, but clusters 1 and 2 were formed in the south area and cluster 4 in the north area, compared to cluster 3 (Fig. 3(D)). The species composition of cluster 1 was dominated by SBT, cluster 2 had similar amounts of SBT, SKX and OTH, cluster 3 was comprised of mainly ALB along with some BET, and cluster 4 was dominated by BET (Figs. 4(D) and 5(D)).

Fig. 6 represents ALB CPUE indices standardized by the lognormal constant model and the delta lognormal model, along with the nominal CPUEs for each region. The standardized CPUE in the western subtropical region (R1) decreased from the early 1980s to the early 1990s, after that showed at low level with a fluctuation, and has increased since the 2010s. In the eastern subtropical region (R2), it showed the similar trend with that of R1 but had no information after the mid-2000s. In the western temperate region (R3), since the early 2000s it has shown an increasing trend. Diagnostic frequency distributions of standardized residuals and Q-Q plot indicate that data fitted the GLM well (Fig. 7).

The influence plots for cluster effect by region by the lognormal constant model are shown in Fig. 8. The pattern of the parameter estimates is shown at the top of each plot, and the influence of each parameter on the year effect on the right side of each plot.

## References


Hoyle S, Chang ST, Fu D, Kim DN, Lee SI, Matsumoto T, Chassot E and Yeh YM. 2019. Collaborative study of bigeye and albacore tuna CPUE from multiple Indian Ocean longline fleets in 2019, with consideration of discarding. IOTC-2019-WPM10-16.

Kitakado T, Wang S-P, Satoh K, Lee SI, Tsai W-P, Matsumoto T, Yokoi H, Okamoto K, Lee MK, Lim J-H, Kwon Y, Su N-J, Chang S-T and Chang F-C. 2021. Report of trilateral collaborative study among Japan, Korea and Taiwan for producing joint abundance indices for yellowfin tuna in the Indian Ocean using longline fisheries data up to 2019. IOTC-2021-WPTT23(DP)-14.

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Lee SI. Lim J-H, Lee MK, Kwon Y. 2021. Korea National Report to the Scientific Committee of the Indian Ocean Tuna Commission, 2021. IOTC–2021–SC24–NR13.

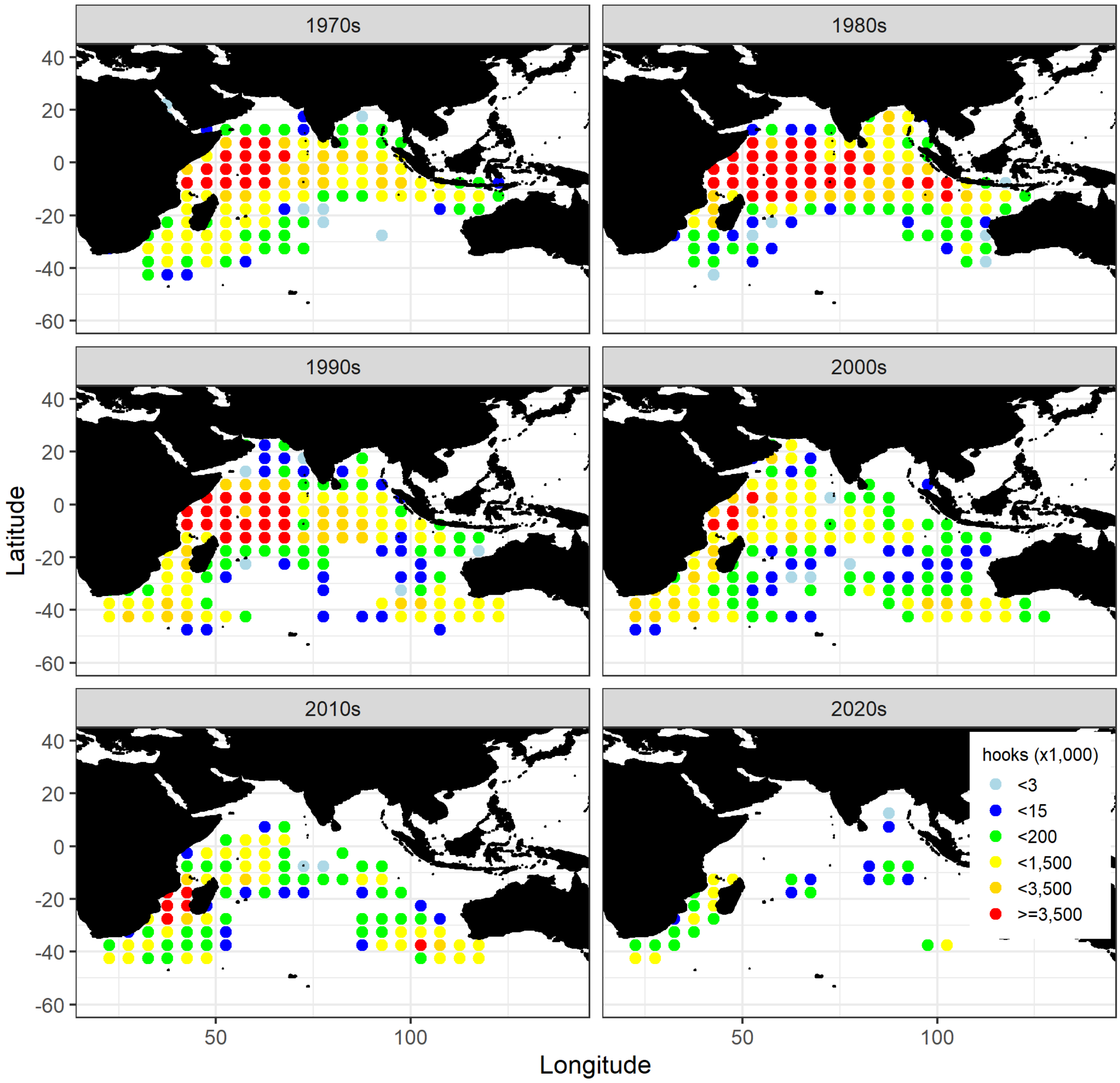



Fig. 1. The geographical distributions of total effort (number of hooks) of Korean tuna longline fishery in the Indian Ocean during the 1970s-2020s.

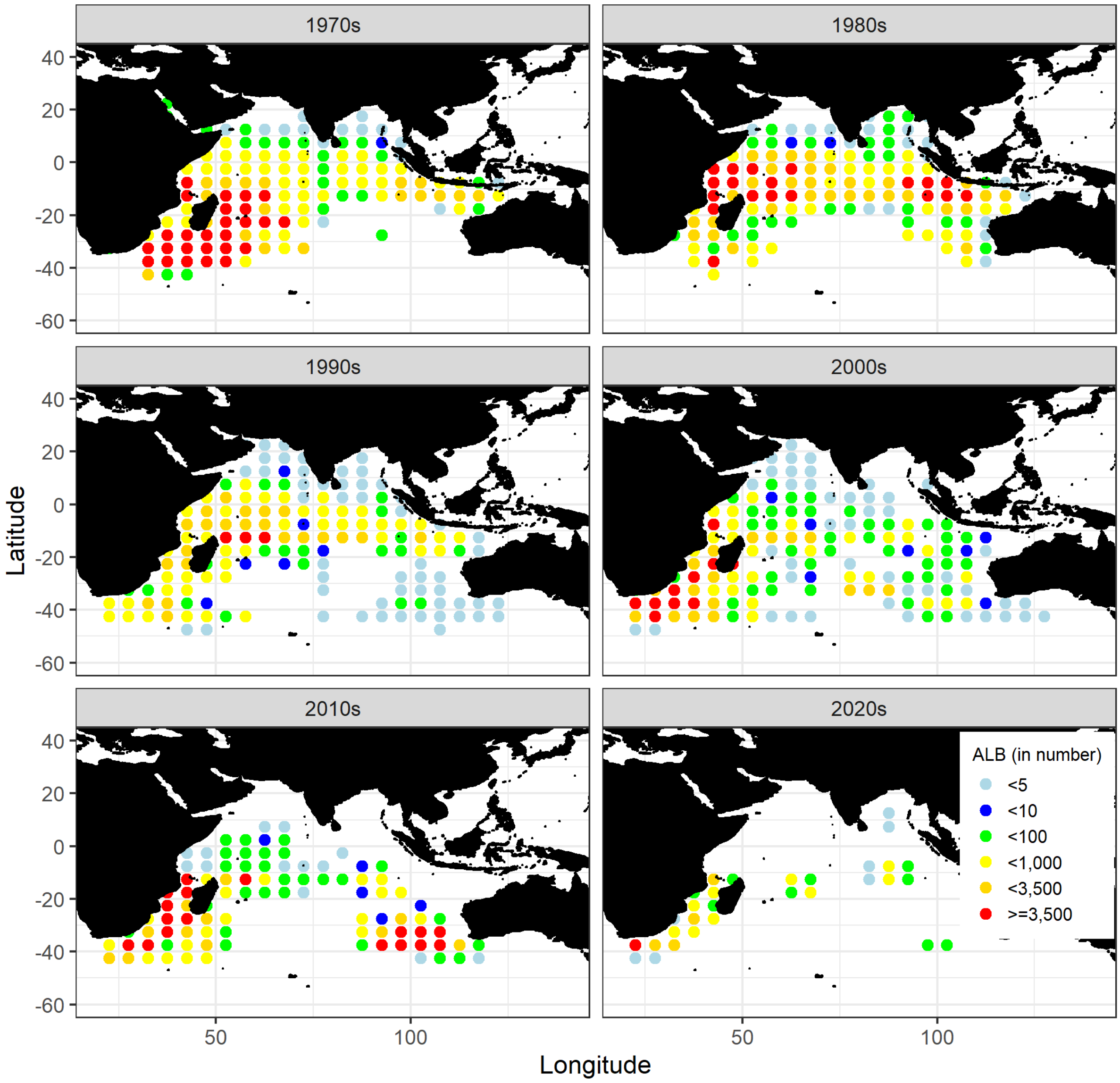



Fig. 2. The geographical distributions of albacore tuna caught by Korean tuna longline fishery in the Indian Ocean during the 1970s-2020s.

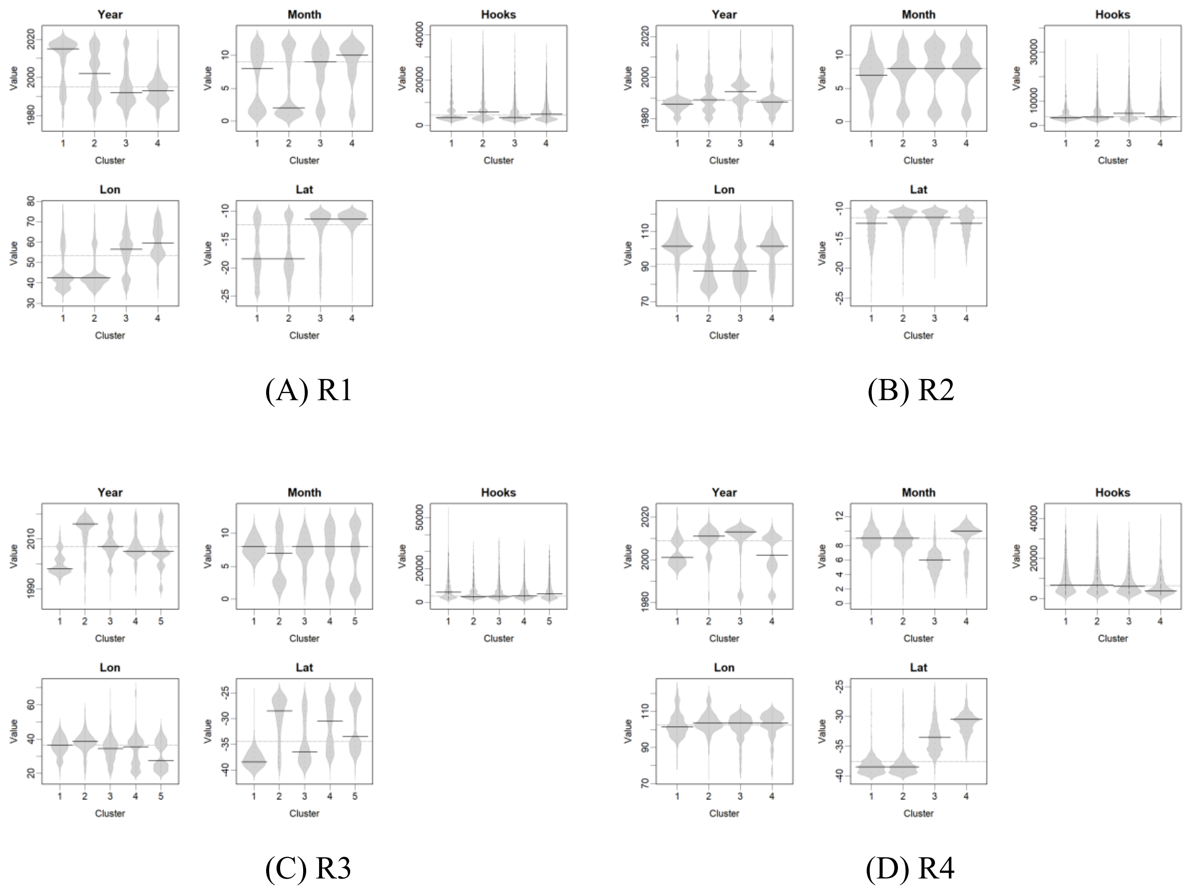
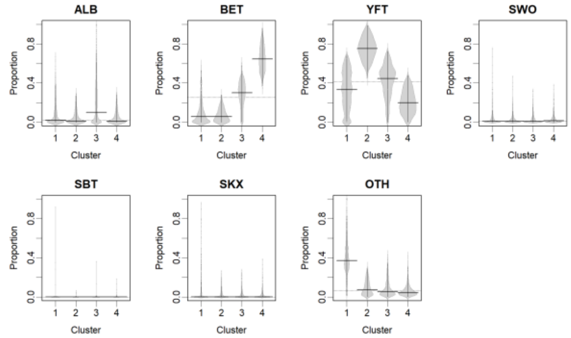
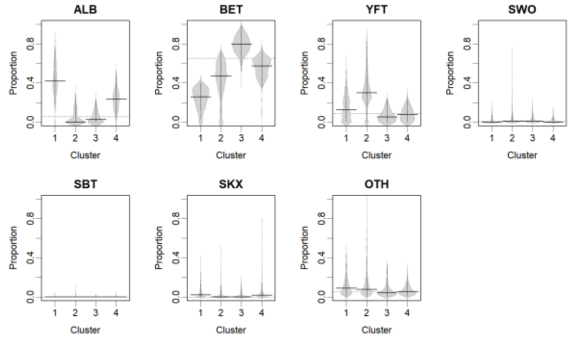


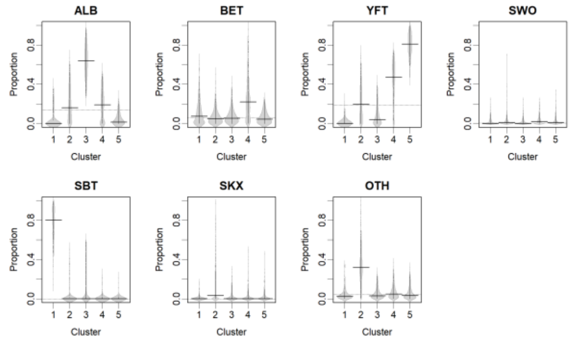

Fig. 3. Beanplots showing the number of sets versus covariate by cluster for each region. The horizontal bar indicates the median.



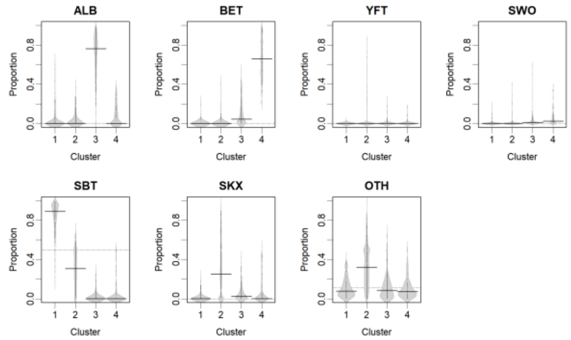

(A) R1




(B) R2

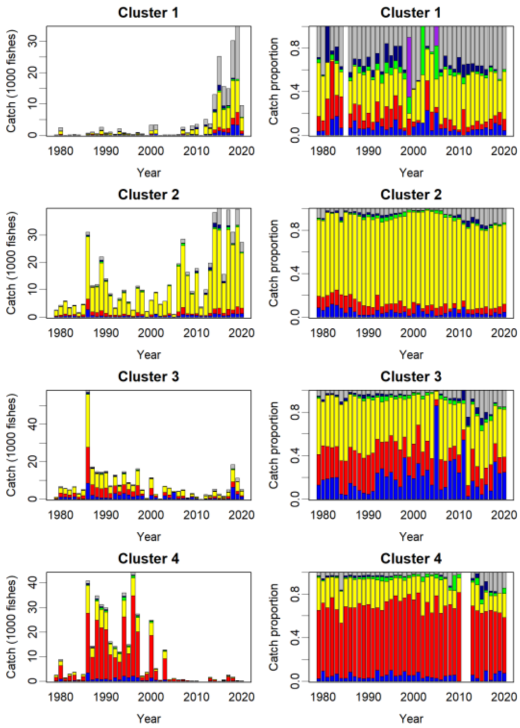



(C) R3

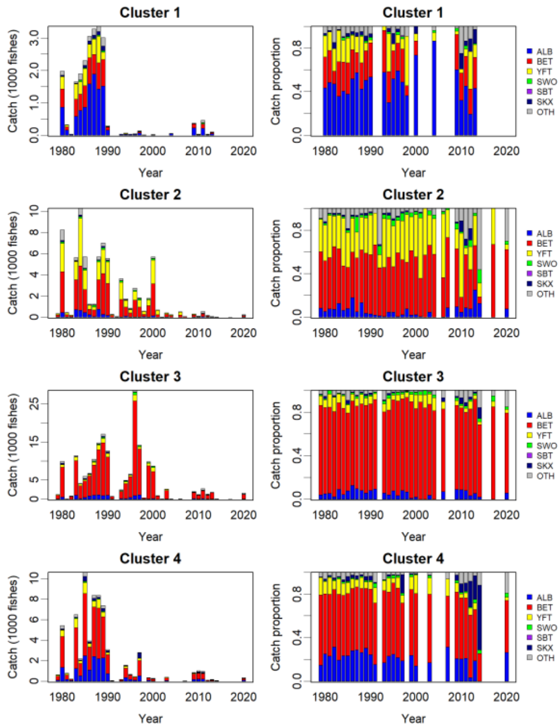



(D) R4

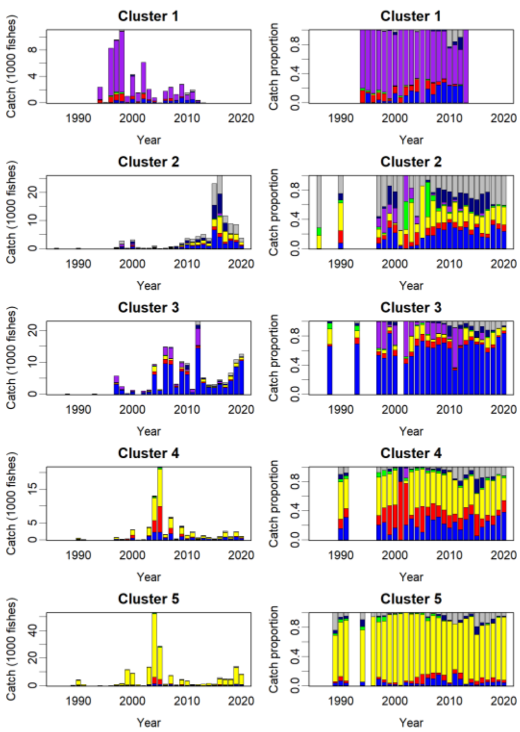
Fig. 4. Beanplots showing species composition by cluster for each region (ALB: albacore tuna, BET: bigeye tuna, YFT: yellowfin tuna, SWO: swordfish, SBT: southern bluefin tuna, SKX: sharks, and OTH: other fishes). The horizontal bar indicates the median.



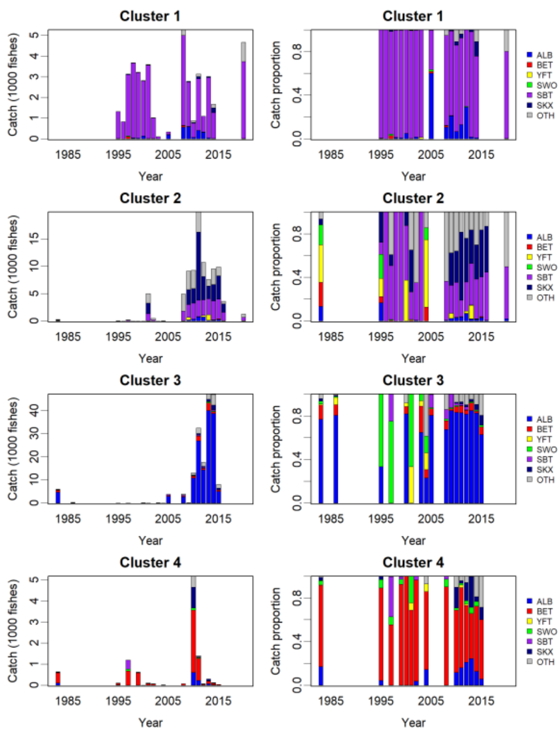

(A) R1




(B) R2




(C) R3




(D) R4

Fig. 5. Annual change in catch and species composition by cluster for each region.

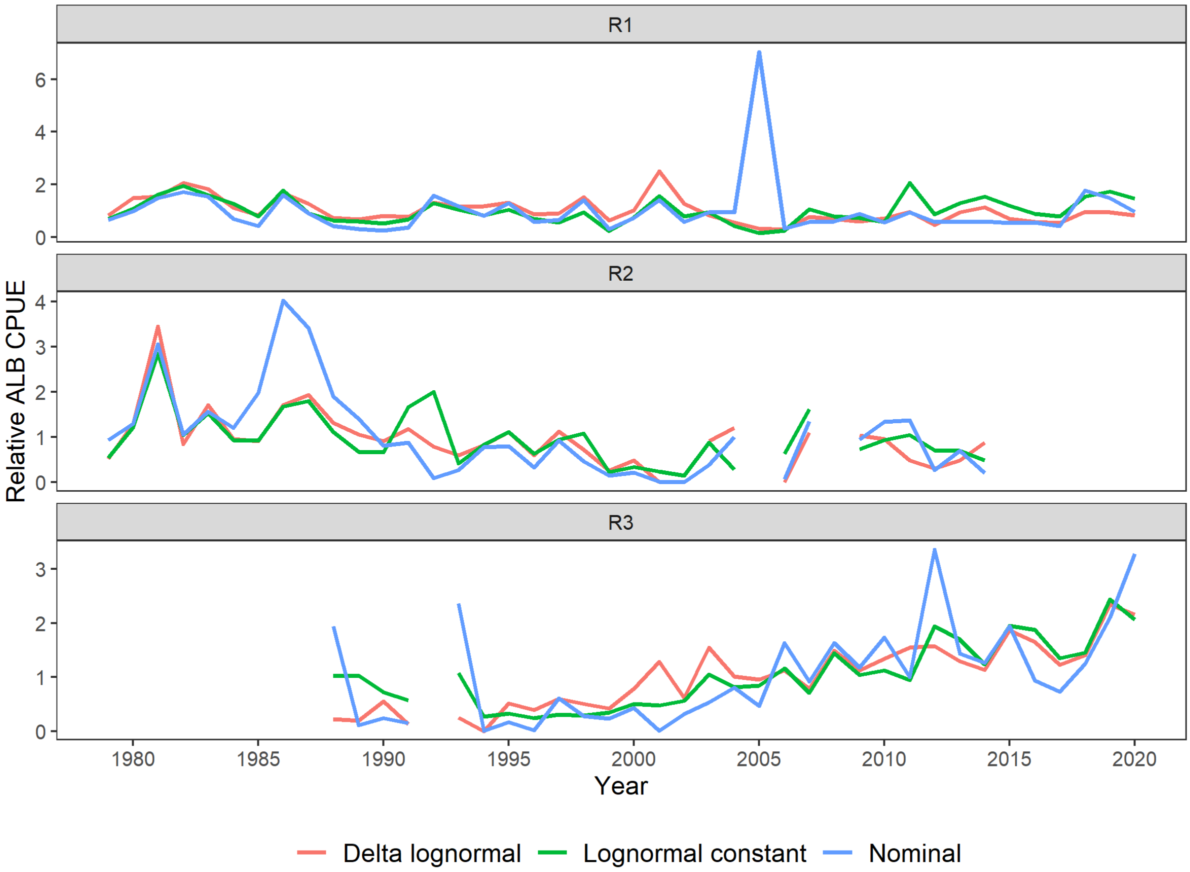
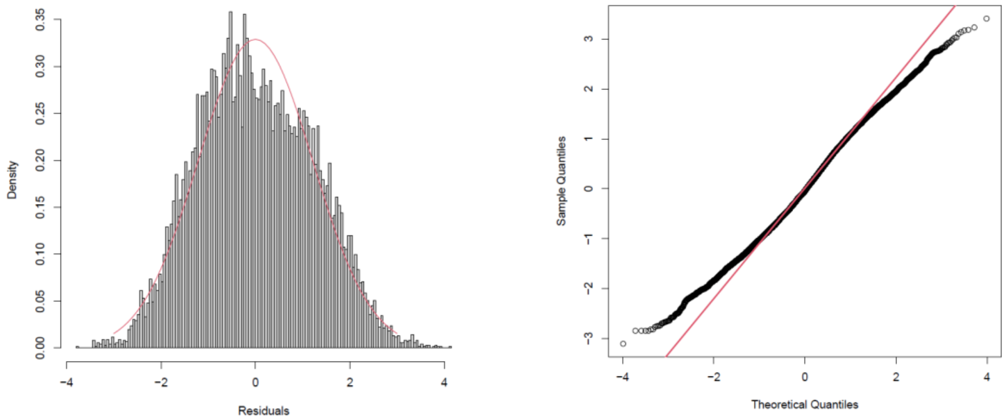
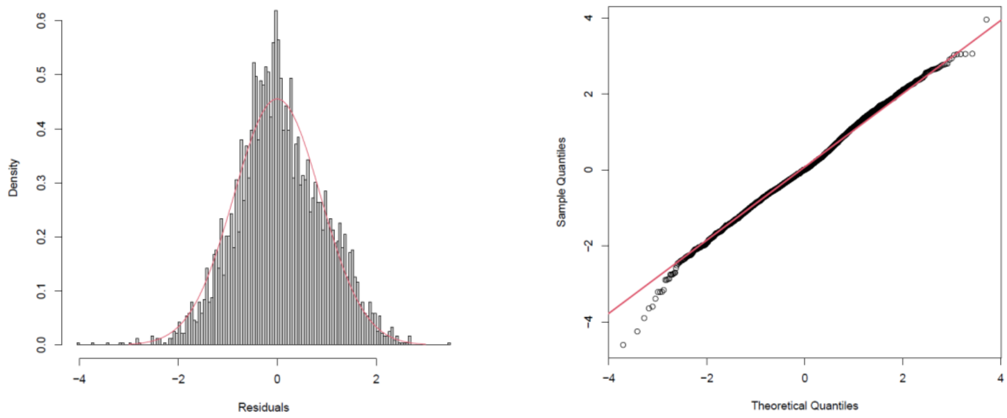


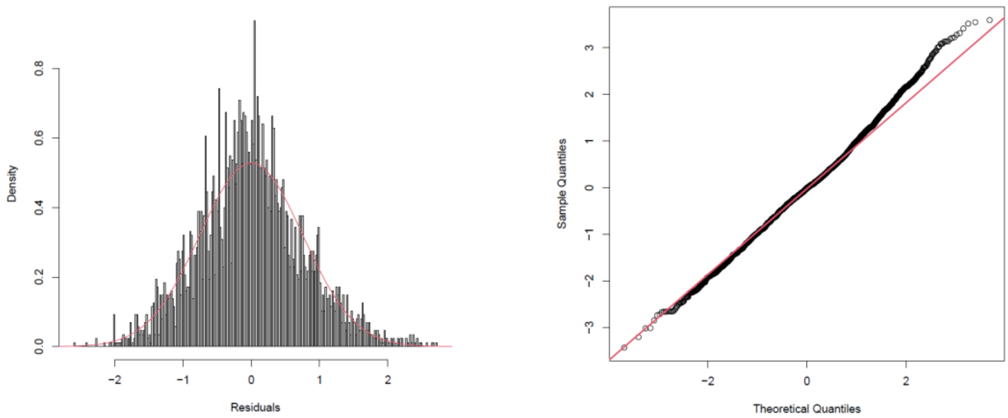

Fig. 6. Standardized albacore CPUE indices from Korean longline fishery by region based on the lognormal constant and delta lognormal models.




(A) R1

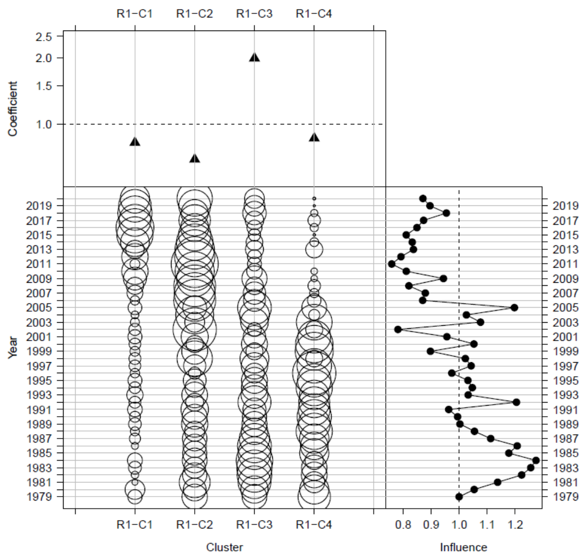



(B) R2

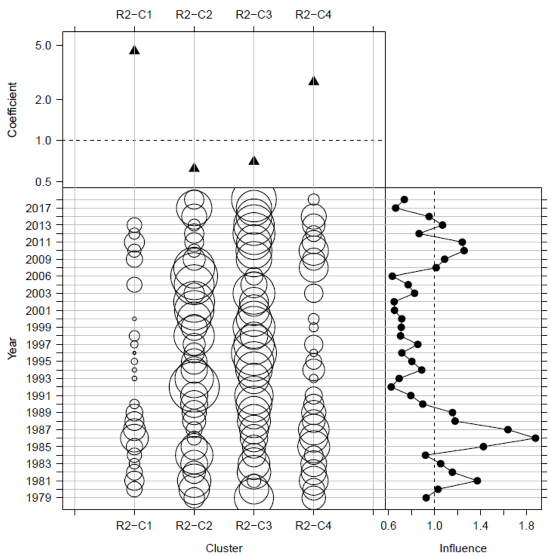



(C) R3

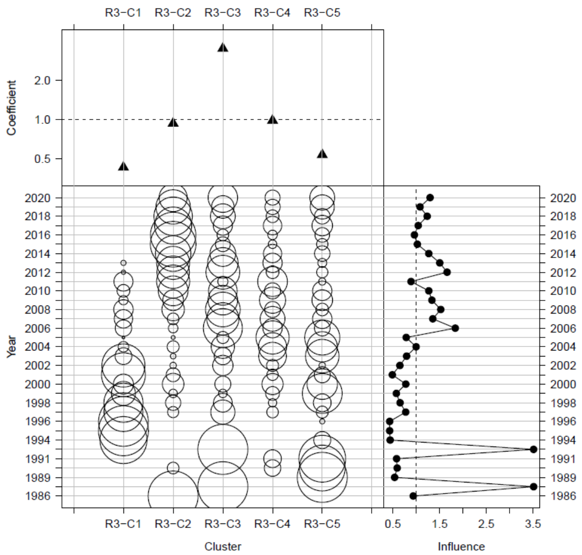
Fig. 7. Frequency distributions of standardized residuals and Q-Q plot of albacore CPUE standardization for each region.




(A) R1




(B) R2




(C) R3

Fig. 8. Influence plots for cluster effect by region.