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UPDATE OF TRILATERAL COLLABORATIVE STUDY AMONG JAPAN, KOREA AND CHINESE TAIPEI FOR PRODUCING JOINT ABUNDANCE INDICES FOR THE ATLANTIC BIGEYE TUNAS USING LONGLINE FISHERIES DATA UP TO 2019

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SUMMARY

Three distant-water tuna longline countries, Japan, Korea and Chinese Taipei, have started a collaborative study since December 2019 for producing the joint abundance indices using integrated fishery data of these fleets to contribute to the upcoming stock assessments of bigeye tuna in the Atlantic Ocean. The intention is to produce reliable indices by increasing the spatial and temporal coverage of fishery data. In this paper, results using data up to 2019 fisheries were provided to update the SCRS on the progress of this activity. As an underlying analysis, a clustering approach was utilized to account for the inter-annual changes of the target in each fishery in each region. 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-degree grid resolution in each region. In addition to the implicit target species through the clustering, geographical and temporal covariates were used in the regression structures. The models were diagnosed by the standard residual plots and influence analysis.

RÉSUMÉ

Le Japon, la Corée et le Taipei chinois, trois pays réalisant des activités de pêche thonière palangrière en eaux lointaines, ont entamé une étude collaborative en décembre 2019 afin de produire des indices d'abondance conjoints en utilisant les données de pêche intégrées de ces flottilles dans le but de contribuer à la prochaine évaluation du stock de thon obèse dans l'océan Atlantique. Le but visé est la mise au point d'indices fiables en augmentant la couverture spatio-temporelle de ces données sur les pêcheries. Dans ce document, les résultats utilisant des données allant jusque 2019 ont été fournis afin de tenir le SCRS au courant des progrès de cette activité. Comme analyse sous-jacente, une approche de regroupement a été utilisée pour tenir compte des changements interannuels du ciblage de chaque pêcherie et de chaque région. Pour standardiser les données de prise par unité d'effort, des modèles linéaires conventionnels et des modèles linéaires delta-lognormaux ont été utilisés pour les données mensuelles avec une résolution en carrés de 1ºx1º dans chaque région. En plus des espèces cibles implicites par le biais du regroupement, des covariables géographiques et temporelles ont été utilisées dans les structures de régression. Les modèles ont été diagnostiqués par les diagrammes standard de valeurs résiduelles et l'analyse d'influence.

RESUMEN

Tres países con pesquerías de palangre de aguas distantes, Japón, Corea y Taipei Chino, han iniciado un estudio en colaboración desde diciembre de 2019 para elaborar índices de abundancia conjuntos utilizando los datos pesqueros integrados de estas flotas para contribuir a las próximas evaluaciones del stock de patudo en el océano Atlántico. La intención es elaborar índices fiables aumentando la cobertura espacial y temporal de estos datos pesqueros.

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En este documento, se facilitan los resultados utilizando datos hasta 2019 para actualizar el progreso del SCRS de esta actividad. Como análisis subyacente, se utilizó un enfoque de conglomerados para tener en cuenta los cambios interanuales de la especie objetivo en cada pesquería y en cada región. Para estandarizar los datos de la captura por unidad de esfuerzo, se utilizaron modelos lineales convencionales y modelos lineales delta lognormales para los datos con una resolución mensual de cuadrículas de 1 grado en cada región. Además de la especie objetivo implícita mediante los conglomerados, se usaron covariables geográficas y temporales en las estructuras de regresión. Los diagnósticos de los modelos se realizaron mediante diagramas residuales estándar y análisis de influencia.

KEYWORDS

Catch/effort, bigeye tuna, joint abundance index, spatio-temporal modelling

Introduction

Tuna-RFMOs, including ICCAT, recommended that the joint CPUE of longline fisheries be developed to improve the stock assessments for tropical tunas, and thus collaborative works have been conducted for several years to produce an abundance index by combining CPUE data from major longline fleets. However, it was found during the meetings that the fishing technologies and data formats were different among the fleets, and therefore it is important to discuss and exchange the information among countries in order to improve the analysis and index. To this end, three longline countries, Japan, Korea and Chinese Taipei, have started a collaborative study for developing the abundance index since December 2019.

Regarding longline CPUE standardization processes, an ensemble approach of fishery data from multiple longline fleets has been applied recently to the Atlantic Ocean tropical tuna species stock assessments (Hoyle *et al.* 2019a, 2019b; Matsumoto *et al.* 2019). The development of joint abundance index was considered to be successful, but it still has some issues to be solved (Anonymous 2018a, 2018b, 2019a and 2019b, Fernández 2019, Methot 2020). In the ICCAT Tropical Tuna Species Group Meeting in July, 2020, the WG recommended further analysis including developing the data sharing protocol and size-based standardized CPUE as follows;

In Section 9 of bigeye tuna data preparatory meeting report (Anonymous 2018a),

> *To the SCRS and CPCs:*
>
> *- Ask all CPCs to commit to develop a joined longline index for tropical tunas based on combining set by set data as it was attempted for the first time during the data preparatory meeting. This would require:*
>
> - *finding a mechanism for sharing the data prior to the data preparatory meetings so as to produce an SCRS paper with the combined index.*
> - *agreeing on a procedure to protect the confidentiality of the national data.*
> - *agreeing on a methodology for the combination of data.*
> - *ensuring that the tropical group scientists have the ability to conduct the analysis (during the current meeting an external scientist led the analysis).*
>
> *To the Stock Assessment Methods Working Group (WGSAM):*
>
> *- To add to the diagnostic section on the guidelines for development of relative abundance indices the production of influence plots for each factor in the model.*
>
> *- To review the following methodological issues associated with combining longline set by set data from different longline fleets for the purposes of standardizing CPUE:*
>
> - *the use of clustering of longline sets based on species composition within a longline set.*
> - *the use of fishing effort (number of hooks per longline set) as an explanatory variable in standardization models.*
> - *investigate the assumptions (explicit and implicit) related to weights assigned to individual longline sets according to the cell such longline*

Also, in Section 2.3 of bigeye tuna stock assessment meeting report (Anonymous 2018b), suggestions were made to investigate to ensure similarity of selectivity patterns of multiple fleets:

1. *More careful examination will be pursued to evaluate if the selectivities are reasonably similar*
2. *The inclusion of time-varying selectivity in the SS3 for a particular fleet should be examined (see proposed guidelines below)*
3. *Use of age/size information for the CPUE standardisation (size‐ or age-based standardized CPUE indices or using the mean size as a covariate) may help reduce or eliminate such a bias.*

Some of these tasks need time to investigate, thus a trilateral framework composed of three longline countries (Japan, Korea and Chinese Taipei) has developed to address these recommendations to some extent as introduced in the 2020 Species group meeting (Satoh *et al.* 2020). In this paper, some preliminary results using data up to 2019 fisheries were provided an update on the progress of this activity to the SCRS. In Section 12.1.9 of 2020 SCRS Advice to the commission (Anonymous 2020), suggestions were made to update combined bigeye tuna longline index of abundance:

> *The Committee will update the combined bigeye tuna longline combined index of abundance for the upcoming assessment in 2021.*

Materials

Data sharing protocol

Initially, the analysis was planned to conduct in a series of in-person meetings through data sharing in an intranet system to ensure the data security. However, after a face-to-face meeting in Busan in December 2019, we have been holding only webinar meetings (a total of 15 times until April 2021) because of COVID-19 pandemic. Under this circumstance, a data sharing protocol was finalized among the three countries 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).

Brief background on fishery

Figure 1 and 2 represent distributions of fishing efforts by decade for longline fisheries of three countries and their annual nominal CPUEs of bigeye tuna in the ICCAT convention area, respectively. The detail information in each country’s fishery is described in working/information papers by each country.

Japan:

Longline is the only tuna-fishing gear deployed by Japan at present in the Atlantic Ocean. Japanese longline in the Atlantic Ocean has long history started in 1956. Japanese longline has huge operation area, and it covers almost entire Atlantic Ocean. Bigeye tuna is one of main target species especially in the tropical area during almost entire period especially after mid-1970s. Information on the catch and effort data is available mainly from logbooks. The detail of the catch and effort for Japanese longline fishery is reported by Matsumoto (2021).

Korea:

Korean tuna longline fishery commenced operating in the Atlantic Ocean since 1964. In the 1970s, Korean longline fishery widely operated in the Atlantic Ocean and its total catch hit the record high of about 47,000 t in 1975. However, the catch had sharply decreased from the early of 1980s, and it showed lower level of below 1,000 t from the late of 1990s to the early of 2000s. Since 2004, it had started to increase and recorded about 4,900 t in 2008, and then it has been fluctuated in the level of around 3,000 t on average. The catch of bigeye tuna had started to increase from the late of 1960s and recorded the highest of about 12,000 t in 1981, then it showed a decreasing trend up to the early of 2000s. The average catch of bigeye tuna is about 1,200 t during the recent decade.

Chinese Taipei:

Distant-water tuna longline fishery by Chinese Taipei started to operate in the Atlantic Ocean from the 1960s to target tropical tunas, including bigeye tuna and yellowfin tuna with the main fishing ground in tropical waters of the Atlantic Ocean. From the mid-1960s, this fishery targeted albacore tuna, and then transferred to yellowfin and bigeye tunas in the late 1980s (Hsu and Liu, 1992). Catches of yellowfin tuna from this fleet remained at a lower level as bycatch, and fluctuated between 100t to 1500t in the early period, but increased dramatically and fluctuated between 3,500t and 7,500t due to the shift of target species and fishing strategy of deep longlining in tropical areas of the Atlantic Ocean (Huang 2019). The catch of bigeye tuna was below 10,000t before 1990, but dramatically increased to more than 10,000 t from 1991 to recent years in response to the targeting change to this species (Huang, 2019). Due to the quota limitation, the catch remains at 13,000t during the recent decade for this fishery (Su *et al.*, 2021).

Brief background on Data set

The data set combined for bigeye CPUE standardization were available from 1975 to 2019, 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), Atlantic bluefin tuna (BFT), southern bluefin tuna (SBT), black marlin (BLM), blue marlin (BUM), swordfish (SWO), other billfishes (BIL), sharks (SKX) and others (OTH). **Table 1** summarizes data available for each country and data set used for the CPUE standardization. **Figure 1** also shows decadal changes in distribution of fishing efforts (number of hooks) for longline fisheries over the fishing ground in the ICCAT convention area. For each region defined in **Figure 2**, plots for the comparison of yearly nominal CPUEs among three countries are provided in **Figure 3.**

Japan:

Japanese longline logbook catch-and-effort data were available from 1975 to 2020 (data for 2020 were preliminary and therefore not used in this analysis). Previous studies (e.g., Hoyle *et al.* 2019 a, b) did not include the fields of vessel identifier before 1978, but it is now available since 1975. Size composition data of bigeye tuna used in this analysis were available from 1975 to 2019, with data fields year, month and day of operation, location to 1° of latitude and longitude, fork length (cm), which was measured by fishermen and observer on board using a straight calliper. The field of the day of operation or the size composition data was only available after 1986, thus the size composition data is not separated into the 10-days interval of which time interval is used in the clustering analysis.

Korea:

Korean catch-and-effort data were available for 1987 to 2019. Size data of bigeye tuna were available for 2002 to 2019, with data fields of operation date, operation location to 1°, fork length (cm), which was measured by fishermen and scientific observers on board using a straight calliper.

Chinese Taipei:

The operational catch-and-effort data for Chinese Taipei were available for the period from 1995-2019, although earlier data before 1995 were provided to help understand this fishery. From 1995, latitude and longitude were reported at 1° resolution by captains for this fishery, with a code to indicate north or south, and west or east. Each set was allocated to regions according to region definitions; sets outside these areas were ignored. Hooks per set were reported in all datasets, with few sets without hooks removed. The column for bluefin tuna was added to record the catch from 1995; prior to this bluefin tuna were not targeting species and rarely to be harvested in this fishery.

Methods

Analytical procedures

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. In addition to the implicit target species through the clustering, geographical and temporal covariates were used in the regression structures. The models were diagnosed by the standard residual plots and influence analysis and compared via the model selection criteria. Besides these conventional regression methods, analyses using an advanced spatio-temporal model, VAST, were attempted for developing abundance indices with additional consideration of spatio-temporal correlations and targets as well as the life stage of bigeye tuna. So, in a nutshell, the approaches are as follows:

1. investigation of better approaches to account for changes in targeting within each country;
2. analyses using conventional regression models (e.g. delta-lognormal model) with geographical, environmental and fishery (including targeting) information for continuity from the previous approaches; and
3. analysis using an advanced spatio-temporal model (VAST) for developing abundance indices with additional consideration of spatio-temporal correlations and size structure.

Cluster analysis in detail

Overview

As an underlying analysis, a clustering approach was utilized to account for the inter-annual changes of the target in each fishery in each region. Due to high dimensionality of fishery data with species composition, a two-step procedure proposed by He *et al.* (1997) was employed. A "K-means clustering" method with a pre-specified enough large number of initial clusters (say *K*, the argument "centers" in "kmeans" of R function) and a chosen random set (the argument "nstart" in "kmeans" of R function) was firstly applied to fine scale fishery data in order to reduce the dimension of data, and then the aggregated data based on the first step were used in the subsequent "hierarchical clustering". In the previous analyses, K-means used to reduce the dimension was only performed for one iteration with low values of "centers" (${}_kP_2 \approx 40$ clusters; k is number of species) and "nstart", which may result in obviously inconsistent clustering results, especially for the dataset with catch composition consisted of mixture species. In the present analyses, the values of "centers" and "nstart" were increased for K-means and the whole process of two-step clustering was repeated through a certain number of iterations with different random seeds for K-means to seek an optimal set with the smallest sum of within-cluster variation obtained from hierarchical clustering. The outputs of the finalized cluster were then used to assign the cluster label fishery target to each catch-effort data.

Dataset

The dataset used for conducting the clustering consisted of *r* (the number of fishing set) x *c* (the number of species) data frame. For the Atlantic Ocean, albacore (ALB), bigeye tuna (BET), yellowfin tuna (YFT), swordfish (SWO), bluefin tuna (BFT), southern bluefin tuna (SBT) and sharks (SKX) were selected as main species and the catches of fishes other than these species were aggregated into a category of others (OTH). In addition, the data were aggregated by 10-days duration (1st-10th, 11th-20th, and 21st~ for each month) based on the agreement of the trilateral collaborative working group.

Specification of analysis (explanation of "distance" etc.)

For the K-means clustering, the trials with various values for the arguments of "centers" (from 40 to 1,000) and "nstart" (from 1 to 100) were tested. The values of "centers=500" and "nstart=30" were chosen since these settings can produce relatively robust results with less computation time for most datasets in different areas, but these values can be adjusted depending on the data.

For the hierarchical clustering, the trials with Ward's minimum variance and the complete linkage methods ("ward.D" and "complete" for the argument "method" in "hclust" of R function) applied to the squared Euclidean distances between data points calculated based on the species composition from the clusters of K-means were also conducted to examine the influence of agglomeration methods on the clustering results. Slight differences in the sum of within-cluster variations were observed from the results obtained using two agglomeration methods but may depend on the data from different areas. Therefore, Ward's minimum variance method, which is commonly used for conducting hierarchical clustering, was adopted for the present analyses. The number of clusters for the hierarchical cluster was determined when both the permutation ANOVA (PERMANOVA) for the centroids of the groups and the Beta diversity test permutation test for the homogeneity of multivariate dispersions achieve significances under the minimum number of clusters (Amruthnath and Gupta, 2019), and the improvement in the sum of within-cluster variations was less than 10%. Visualization diagnostics are also conducted based on the plots of centroids by clusters (boxplot and TukeyHSD) and plot from the principal coordinate analysis (PCoA) for the multivariate dispersions by clusters (Amruthnath and Gupta, 2019).

Selection of the final number of clusters

A total of 30 iterations were repeated for each set of two-step clustering process with different random seeds for K-means. The mode of the number of clusters obtained from 30 iterations was selected as the optimal number of clusters. Then the final outcome of the clustering was adopted based on the lowest value of the sum of within-cluster variation within the iterations with the optimal number of clusters.

Conventional regression analyses -LN model-

Log-normal regression models with a constant adjustment

Given that around 8.4% of the catch data are 0, 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, month, quarter, year*quarter)
- Spatial component (5° squared longitudinal and latitudinal grid)
- Vessel ID
- Target (cluster outcomes to express target species of fishery)
- Number of hooks
- Interactions

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 default. Detailed information is shown in each country's document (Matsumoto *et al.* 2021, Lee *et al.* 2021 and Su *et al.* 2021).

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

In addition to the standard residual plots for the diagnosis for fitting of models to the data and Q-Q plots, we used influence plots (Bentley *et al.* 2011) to interpret the contribution of each covariates to the difference between nominal and standardized temporal effects (year or year*quarter).

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.

Potential applications of regional scaling factors (concepts, models and interpretations)

Since we analyse the data by region to produce region-wise index, standardized CPUE series in different regions should have different catchability coefficients while that coefficient can be assumed to be common. However, the stock assessment integrates these CPUE series to produce a single and overall biomass and therefore it would be beneficial to produce another standardized CPUE, which can be directly comparable in terms of magnitude over regions. For this purpose, a method of regional scaling has been developed (Hoyle and Langley 2020). Here, due to a time constraint, we have not applied the method to our data formally, we will attempt the approach when updating the analysis with the finalized dataset including 2020 fishery data.

Conventional regression analyses -Delta-lognormal model-

Delta-lognormal regression model

A delta-lognormal model was also employed 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.

Diagnosis (Residual, influence plots)

The standard residual and Q-Q plots were used for the positive catch model although the influence plots were examined for both the components.

Extracts of abundance indices from two-step models with interactions

Once the model fitting and model evaluation were conducted, the final output of the abundance index is extracted through by the product of the LS means of positive catches and the standardized probability of "non-zero" catches.

Spatial-temporal analyses

Background

To express the spatial distribution, the generalized additive models (GAMs) tend to be useful, but it cannot deal with island/barrier/edge effects. The Gaussian Markov Random Field (GMRF) can account for them through triangulation of the domain with irregular shapes. Use of INLA is convenient for this process but it relies on Bayesian framework. For the maximum likelihood estimation, use of Template Model Builder (TMB) is recommended after use of INLA only for triangulation because of availability of well-prepared approximation of stochastic partial differential equation (SPDE) function. In addition to the spatial component, the spatio-temporal auto-correlation helps to express inter-annual changes in the distribution patterns with use of philosophy of "borrowing strength" over space and time to draw information on density in space and time. These concepts have been achieved and implemented in the vector auto-regressive spatio-temporal (VAST) models with the advantage of faster computation with automatic differentiation and SPED approximation in the TMB.

Formulation and implementation of VAST

We used a package of VAST (Thorson and Barnett 2017; Thorson 2019). The spatial and temporal autocorrelations were incorporated in both of the delta and positive catch components. In addition, the difference in catchability over regions, fisheries and clusters were accounted in the model.

Extension of models with information on life stage

Regarding size specific VAST model, if the two datasets (logbook and size composition data) were aggregated in monthly intervals and 1° square grid, and then merged, which can be enable us to conduct the full time period analysis after 1975. The catch and effort data point without size composition data was removed and then not used for the size specific VAST model. The size composition data was converted to age using the following criteria, age 2 (FL > 85 cm and =< 110 cm), age 3 (FL > 110 cm and =< 130 cm), age 4 (FL > 130 cm and =< 145 cm) and age 5+ (FL > 145 cm), which were based on a growth curve (Hallier *et al.* 2005; $L = 217.3 * (1 – \exp (-0.18 * (t + 0.709)))$).

Note on the VAST analyses

At the time of submission, there have been computational issues such as the convergence, and the authors have not yet gotten reasonable results. However, the work using actual data has just started, and therefore our efforts will be spent more before the upcoming BET stock assessment meeting.

Results

Cluster analysis

Detailed information on outcomes of the clustering is shown in each country's paper, and therefore only brief information is given in this paper.

Japan:

The group numbers by the three regions were 5, 4 and 3 determined by the cluster analysis, of which species compositions were shown in **Figure 4-(a)**. In temperate regions 1 and 3, clusters targeting temperate tuna species, bluefin tuna and albacore were included. In all the three regions, there were clusters targeting bigeye, and bigeye catches of those clusters were higher than other clusters (see **Figure 4-(a)**).

Korea:

For Korean fleet, four clusters were chosen in each region. In region 2 the species composition of cluster 1 comprised almost bigeye, cluster 2 was dominated by yellowfin, followed by bigeye, cluster 3 showed more bigeye along with yellowfin, albacore and swordfish, and cluster 4 had bigeye along with similar amount of sharks, and some yellowfin, swordfish and albacore. In region 3, cluster 1 was dominated by albacore, followed by bigeye, cluster 2 had similar amounts of bigeye and sharks, cluster 3 showed higher bigeye along with some yellowfin, and cluster 4 had more yellowfin along with bigeye and albacore (see **Figure 4-(b)**).

Chinese Taipei:

The optimal group numbers were the lowest value of *k* after which the rate of decline of deviance became slower and smoother. There were 4, 4, and 5 groups for the 3 regions determined using the cluster analysis. Catch composition for each group were shown for regions 1-3. As expected, the cluster 2 in region 1 and cluster 1-3 in region 3 were targeting albacore tuna, while the cluster 3 in the tropical Atlantic Ocean targeted bigeye tuna and the catches were higher than other clusters (see **Figure 4-(c)**).

Conventional regression analysis

Full comparison thought diagnosis and model selection criterion has not yet reached, but examples of results for the following models are shown in **Figure 5 and 6** for the annual and quarterly models, respectively. Also, some plots regarding residuals and influence of the covariate for the quarterly DL model is also shown in **Figures 7 and 8**, respectively.

*Annual LN: Year + Quarter + LonLat + Cluster + Vessel + Year*Quarter*

*Annual DL: Year + Quarter + LonLat + Cluster + Vessel + Year*Quarter [for each component]*

Quarterly LN: YrQ + LonLat + Cluster + Vessel

Quarterly DL: YrQ + LonLat + Cluster + Vessel [for each component, random effects for Vessel in R3 only]

Decreasing patterns were similar over the different models, but there were still some rooms for improvement. One apparent issue is some observed spikes in R1 in the quarterly DL model (see **Figure 6-R1**). Also, R2 in the same model, a slightly unfavourable residual pattern is observed (see **Figure 6-R2**). Perhaps due to mixture of CPUE over three countries, a conventional 10% adjustment factor tends to produce negative values of standardized CPUE, so we conducted some analyses with 1% in some area (see the caption of **Figure 6**, and **Figure 9** to see the impact).

Ways Forward

Update of analysis using data up to 2020 fisheries

Because of delayed and difficulty in data-sharing process, the results shown in this paper were still preliminary. Once 2020 data set is ready for use for re-clustering and re-standardization of CPUE, we will conduct our full analysis to provide a final set of results including VAST analysis based on the updated data including 2020 fishery outcomes before the upcoming bigeye stock assessment meeting scheduled in July 2021 for use as inputs for the update of its stock assessment. In addition, analyses can be further updated if some extra data are available from other longline countries. *(Note that there may not be enough data of size in 2020 due to COVID-19 pandemic)*

Evaluation of uncertainty

Although we have prepared for “bootstrap option” for assessing the standard error and used it as a trial in each country’s data, it takes longer time to complete for joint CPUE and therefore it was not used for the joint analysis yet. We will also report on this issue in case there is a significant difference or not.

Regional scaling factor

As future works, regional scaling will be applied for the conventional regression models so that a constant catchability can be assumed across the regions in the stock assessment models. The regional trends in the standardized CPUE are then compared to those from the VAST analysis, where catchability is constant by default and the regional scaling is not required.

Plan of submission

Although the results shown in this paper were still preliminary because of delayed and difficulty in data-sharing process, a final set of results based on the updated data including 2020 fishery outcomes will be submitted before the upcoming bigeye stock assessment meeting scheduled in July 2021 for use as inputs for the update of its stock assessment. In addition, analyses can be further updated if some extra data are available from other longline countries.

References

Amruthnath, N., Gupta, T. 2019. Fault diagnosis using clustering. What statistical test to use for hypothesis testing? Machine Learning and Applications: An International Journal (MLAIJ) Vol.6, No.1.

Anonymous 2018a. Report of the 2018 ICCAT bigeye tuna data preparatory meeting. (Madrid, Spain 23-27 April, 2018). pp. 1-44.

Anonymous 2018b. Report of the 2018 ICCAT bigeye tuna stock assessment meeting. (Pasaia, Spain 16-20 July, 2018). pp. 1-92.

Anonymous 2019a. Report of the 2019 ICCAT yellowfin tuna data preparatory meeting. (Madrid, Spain 22-26 April, 2019). pp. 1-42.

Anonymous 2019b. Report of the 2019 ICCAT yellowfin tuna stock assessment meeting. (Grand-Bassam, Cote d'Ivoire, 8-16 July 2019). pp. 1-118.

Anonymous 2020. 2020 SCRS Advice to the commission. (Madrid, Spain). pp. 1-355.

Bentley, N., Kendrick, T.H., Starr. P.J. and Breen P.A. 2012. Influence plots and metrics: tools for better understanding fisheries catch-per-unit-effort standardizations. ICES J. Mar. Sci. 69(1): 84-88.

Fernández, Carmen. 2019. External review of ICCAT bigeye tuna stock assessment. Collect. Vol. Sci. Pap. ICCAT, 75(7): 2247-2258.

He, X., Bigelow, K.A., Boggs, C.H. 1997. Cluster analysis of longline sets and fishing strategies within the Hawaii-based fishery. Fish. Res. 31: 147-158.

Hallier, J.P., Stequert, B., Maury, O., and Bard, F.X. 2005. Growth of bigeye tuna (*Thunnus obesus*) in the eastern Atlantic Ocean from tagging-recapture data and otolith readings. (ICCAT SCRS/2004/039). Col. Vol. Sci. Pap. ICCAT, 57(1): 181-194.

Huang, H. W. 2019. Standardized CPUE of bigeye tuna (*Thunnus obesus*) of the Chinese Taipei longline fisheries operated in the Atlantic Ocean (1967-2017). Collective Volume Scientific Papers ICCAT, 75(7), 1946-1967.

Hoyle, S.D., Huang, J. H.W., Kim, D.N., Lee, M.K., Matsumoto, T., Walter, J. 2019a. Collaborative study of bigeye tuna CPUE from multiple Atlantic Ocean longline fleets in 2018. Collect. Vol. Sci. Pap. ICCAT, 75(7): 2033-2080.

Hoyle, S.D., Lauretta, M., Lee, M.K., Matsumoto, T., Sant'Ana, R., Yokoi, H., Su, N.J. 2019b. Collaborative study of yellowfin tuna CPUE from multiple Atlantic Ocean longline fleets in 2019. Collect. Vol. Sci. Pap. ICCAT, 76(6): 241-293.

Hoyle, S.D., Langley, A.D. 2020 Scaling factors for multi-region stock assessments, with an application to Indian Ocean tropical tuans. Fish. Res. 228 https://doi.org/10.1016/j.fishres.2020.105586

Hsu, C. C. and Liu, H. C. 1992. Status of Chinese Taipei longline fisheries in the Atlantic. Collect. Vol. Sci. Pap. ICCAT, 39, 258-264.

Lee, S.I, Lee, M.K., Kwon, Y., Lim J.H. 2021 Update of information on Korean tuna longline fishery and CPUE standardization of bigeye tuna in the Atlantic Ocean. SCRS/2021/053.

Matsumoto, T. 2021. Review of fishing operation and bigeye tuna catch by Japanese longline fishery in the Atlantic Ocean. SCRS/2021/051. pp. 1-25.

Matsumoto, T., Satoh, K., Kitakado, T., Wang, S.P., Su, N.J., and Yeh, Y.M. 2019. Comparison of yellowfin tuna CPUE and length composition between the Chinese Taipei and Japanese longline fisheries in the Atlantic Ocean. SCRS/2019/060, ICCAT Yellowfin Tuna Data Preparatory Meeting, 22-26 April 2019, Madrid, Spain. pp. 1-30.

Methot, R. 2020. (DRAFT) External review of Atlantic yellowfin tuna assessment in 2019. Collect. Vol. Sci. Pap. ICCAT, 76(6): 992-996.

Satoh, K., Matsumoto, T., Yokoi, H., Okamoto, K., Lee, S., Lee, M., Lim, J., Wang, S., Su, N., Tsai, W., Chang, S. and Kitakado, T. 2020. Trilateral collaborative study among Japan, Korea and Chinese Taipei for producing joint abundance index by longline fisheries for the tropical tuna species in the Atlantic Ocean. Collect. Vol. Sci. Pap. ICCAT, 77(8): 151-161.

Su, N.J, Lin, W.R., Huang, W.H. 2021. Catch and effort standardization for bigeye tuna (*Thunnus Obesus*) caught in the Chinese Taipei distant-water longline fishery in the Atlantic Ocean. SCRS/2021/059.

Thorson, J.T., Barnett, L.A.K., 2017. Comparing estimates of abundance trends and distribution shifts using single- and multispecies models of fishes and biogenic habitat. ICES J. Mar. Sci. 74, 1311–1321.

Thorson, J.T., 2019. Guidance for decisions using the Vector Autoregressive Spatio-Temporal (VAST) package in stock, ecosystem, habitat and climate assessments. Fish. Res. 210, 143–161.

Table 1. Summary of data available for each country and data set used for bigeye CPUE standardization (see **Figure 2** for the definition of the region).

Fleet	***Catch and effort data***		***Size data***		***Remarks***
	Period	***Region***	***Period***	***Region***	
Japan	1975-2019 (1956-2020)	R1, R2, R3	1975-2019 (1965-2019)	R1, R2, R3	
Korea	1987-2019 (1971-2019)	R2, R3	2002-2019 (2002-2019)	R2, R3	R1 was not included due to insufficient data.
Chinese Taipei	1995-2019 (1967-2019)	R1, R2, R3	1995-2019 (1995-2019)	R1, R2, R3	Since 1995 operation position has reported at 1° resolution.
Combined	1975-2019	R1, R2, R3	1975-2019	R1, R2, R3	

* Numbers in parentheses indicate the period of data held by each country.

a) Japan

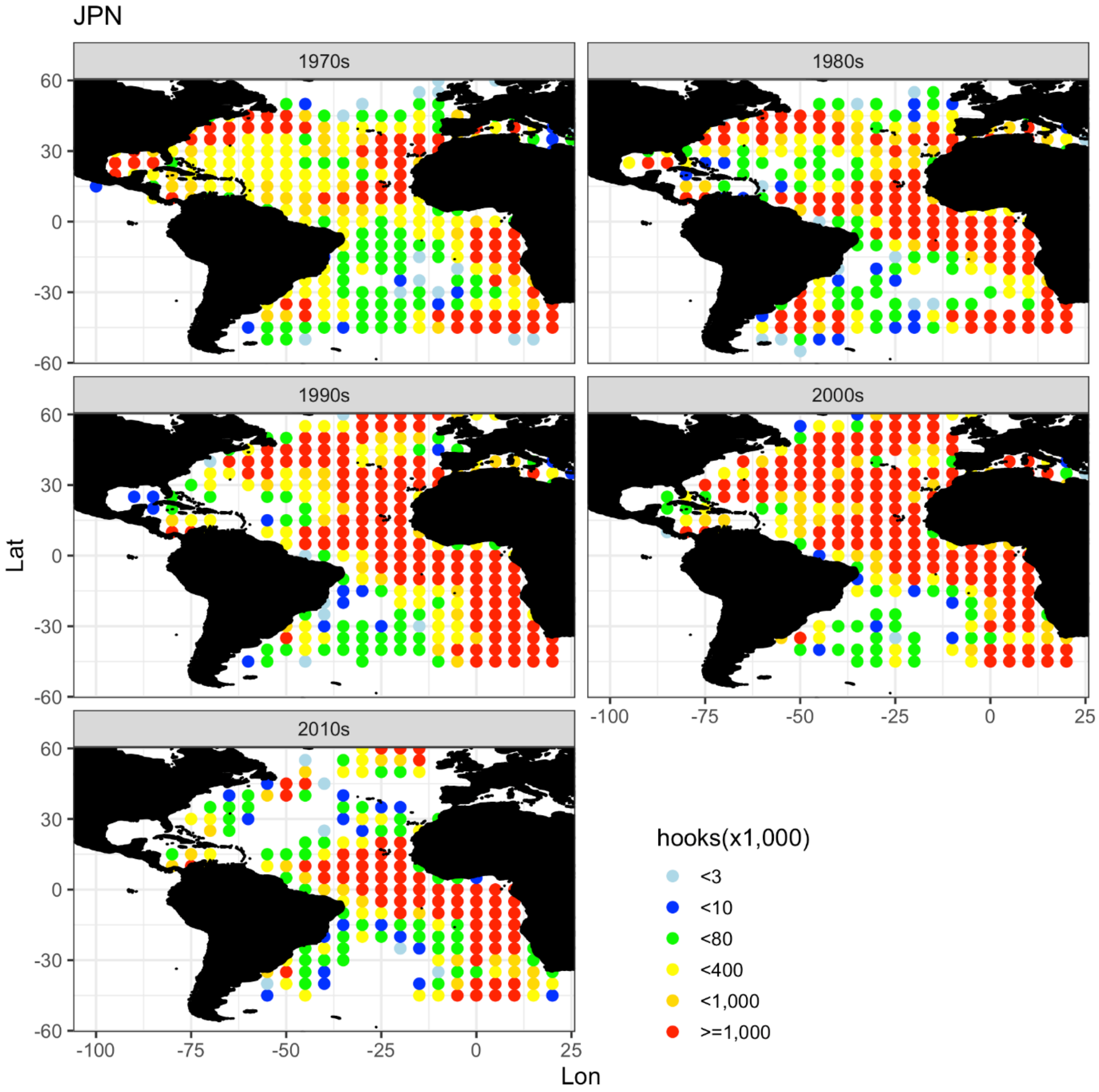


Figure 1. Decadal distributions of fishing efforts (number of hooks) for longline fisheries over the fishing ground in the ICCAT convention area.

b) Korea

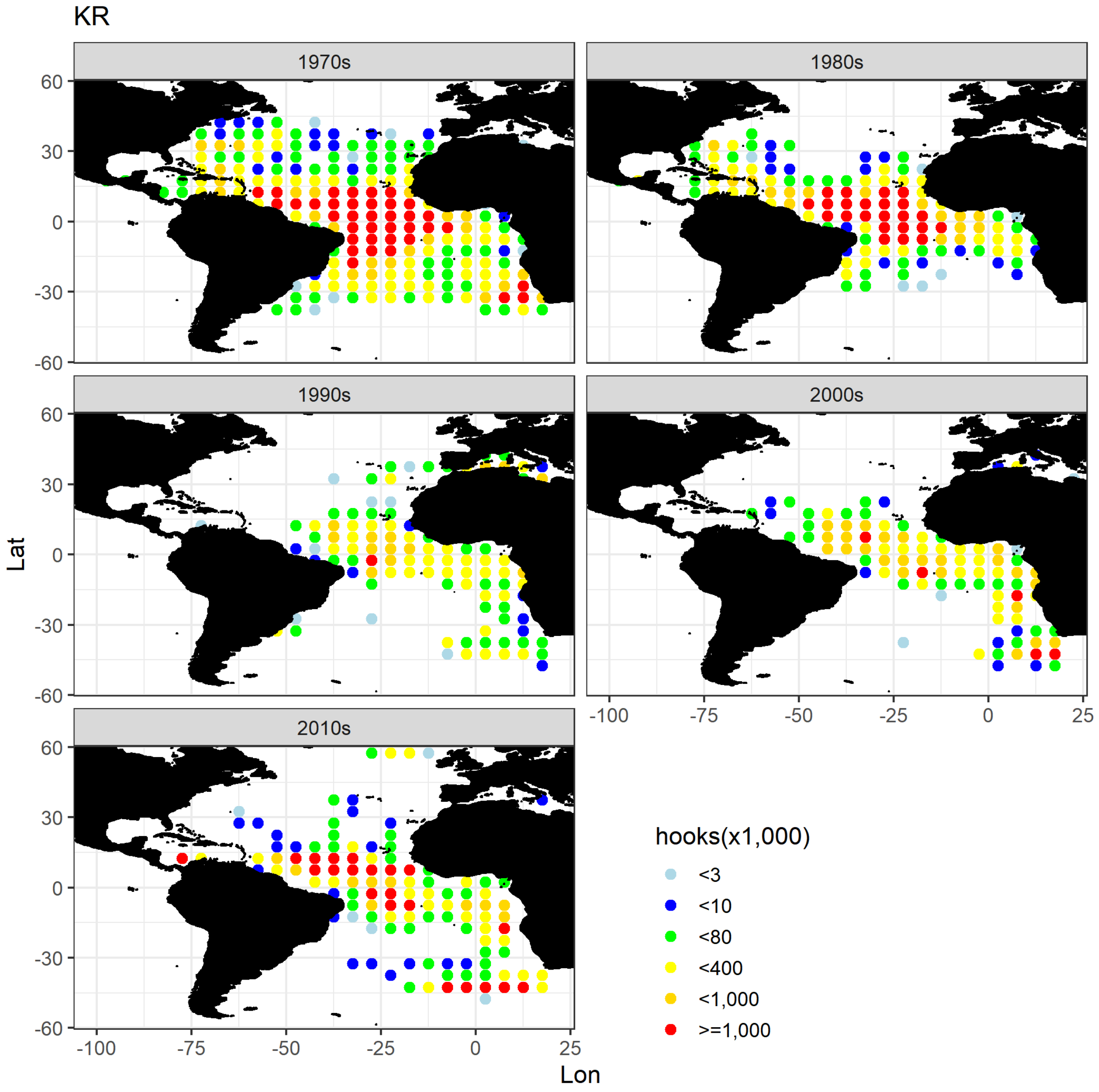


Figure 1 (Continued).

c) Chinese Taipei

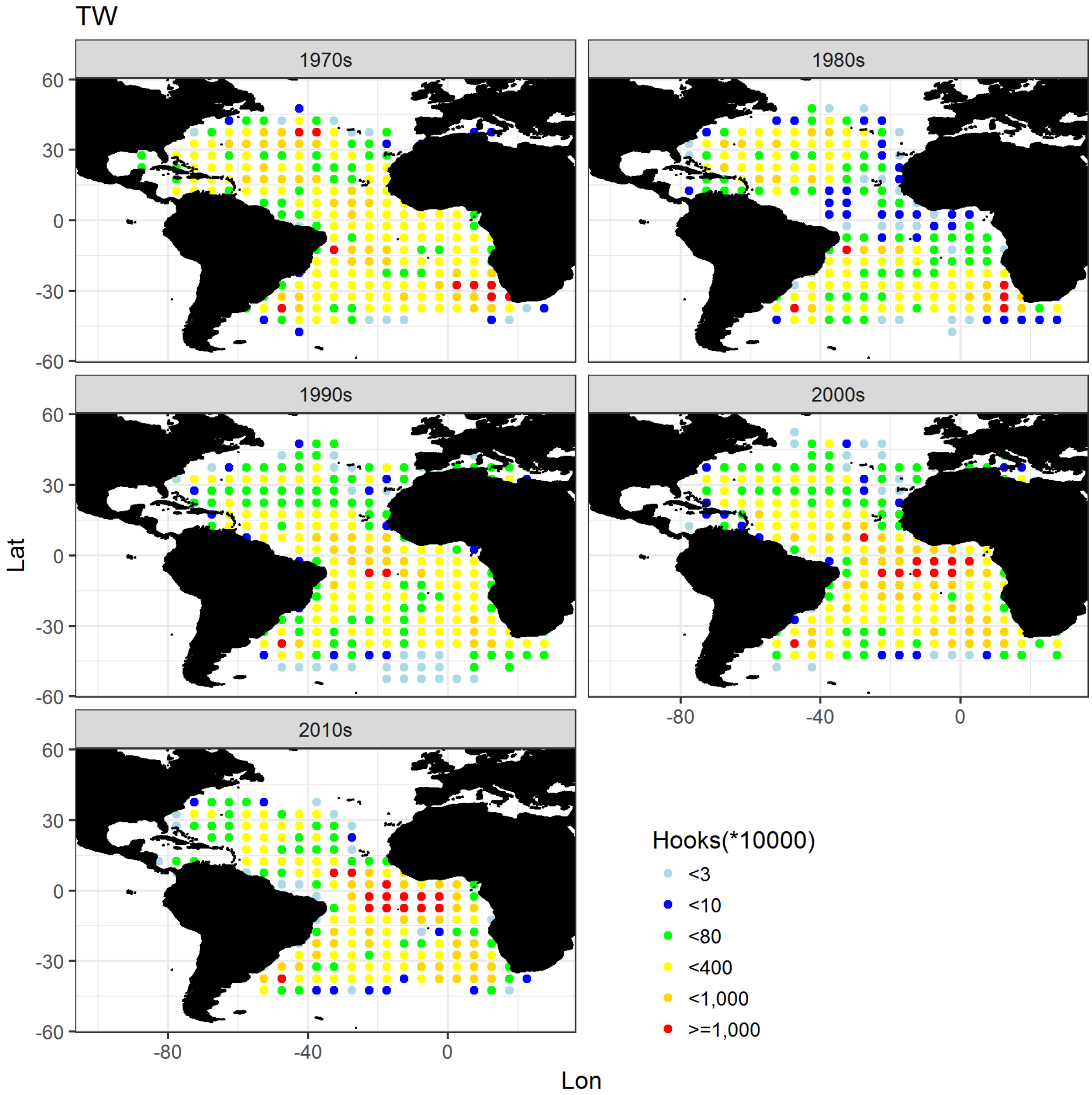


Figure 1 (Continued).

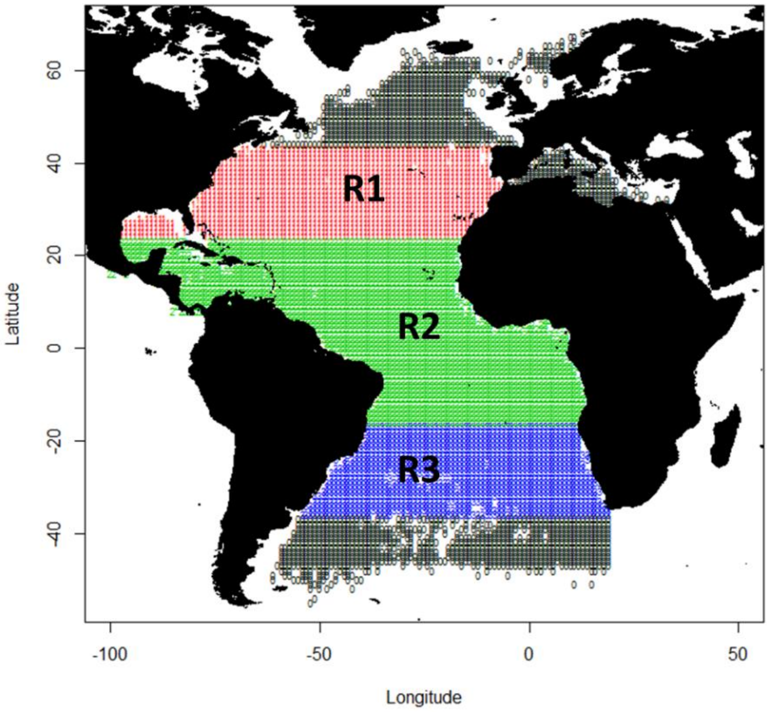


Figure 2. Map of the regional structures used to estimate bigeye CPUE indices.

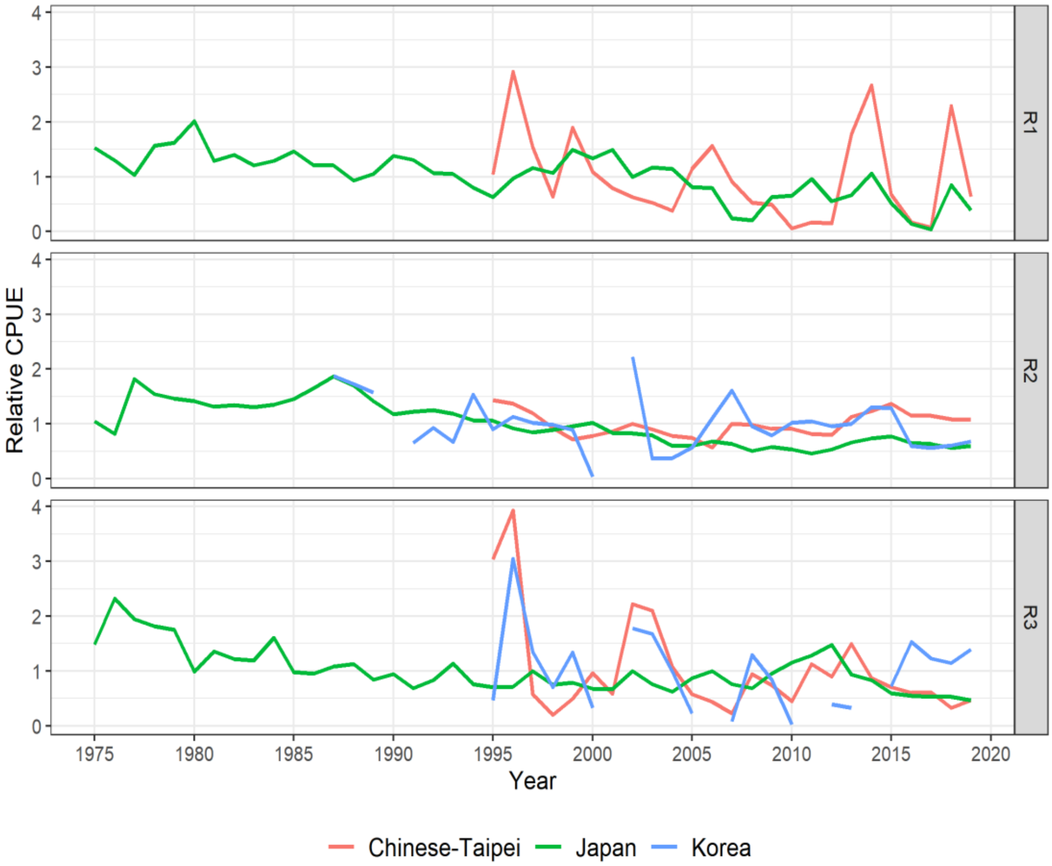
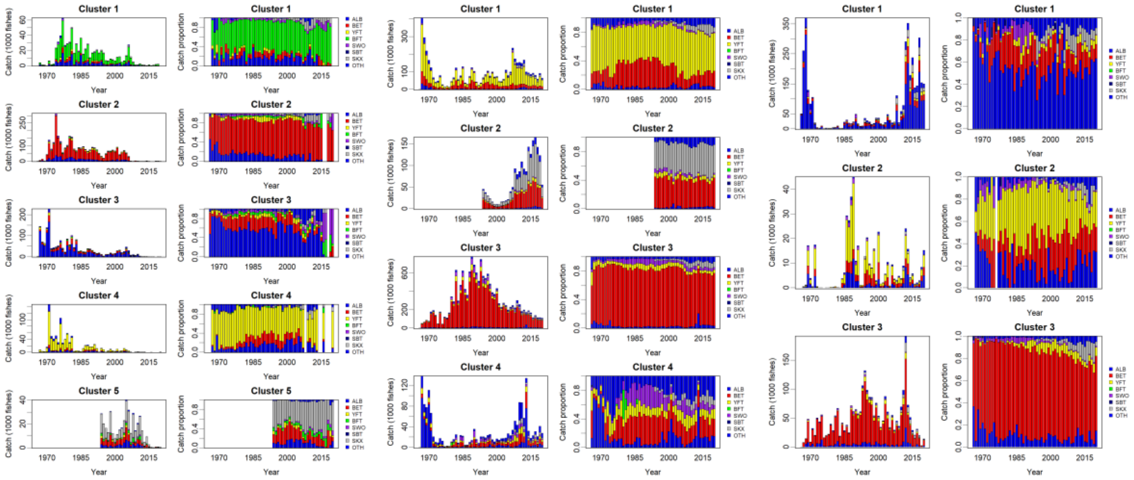
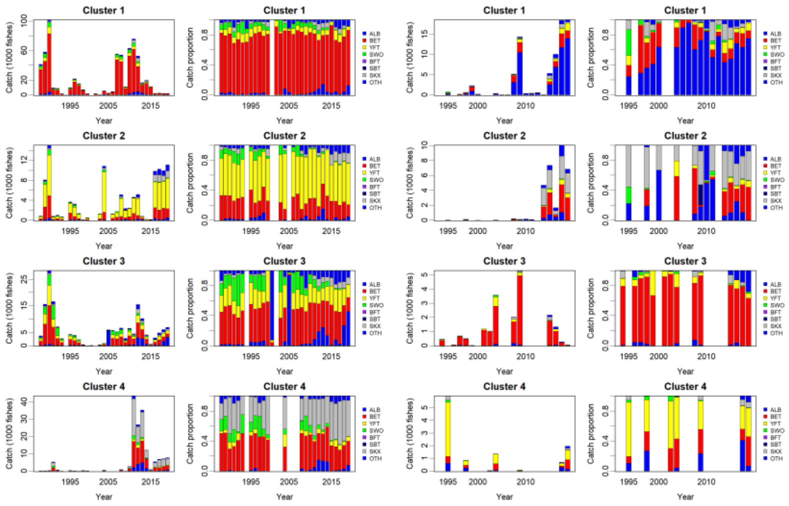


Figure 3. Time series of nominal CPUE of bigeye tuna for longline fisheries in the ICCAT Convention area.

(a) Japan (left: R1, middle: R2, right: R3)



(b) Korea (left: R2, right: R3)



(c) Chinese Taipei (left: R1, middle: R2, right: R3)

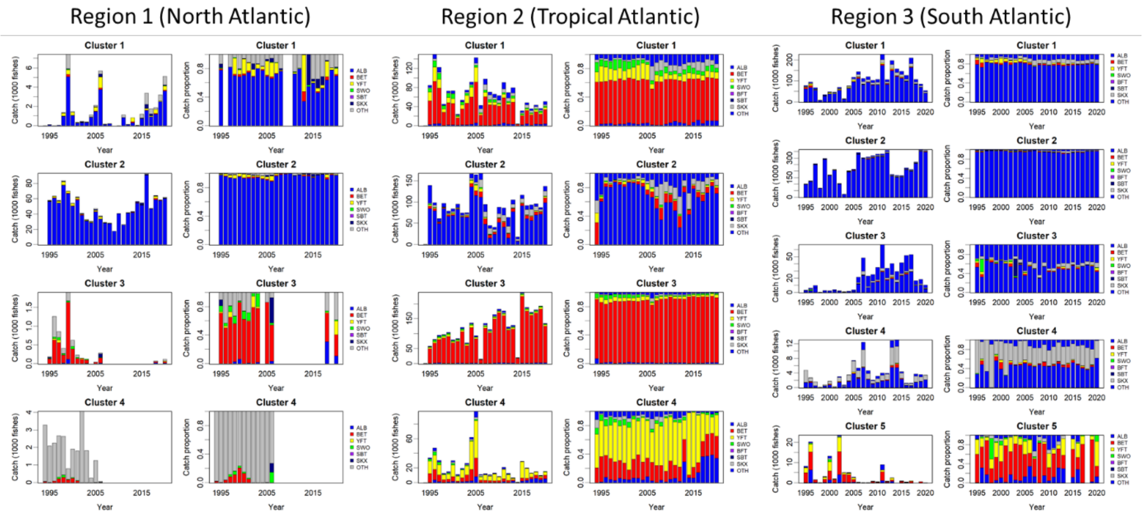
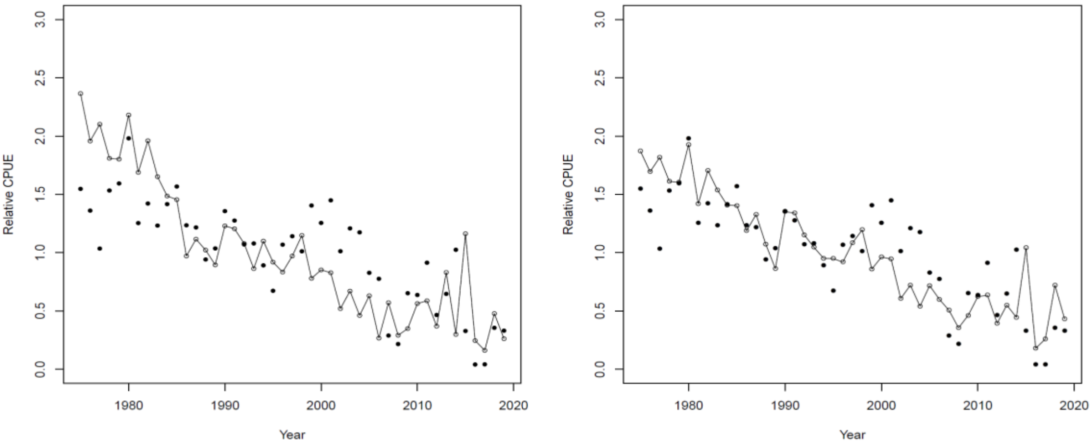
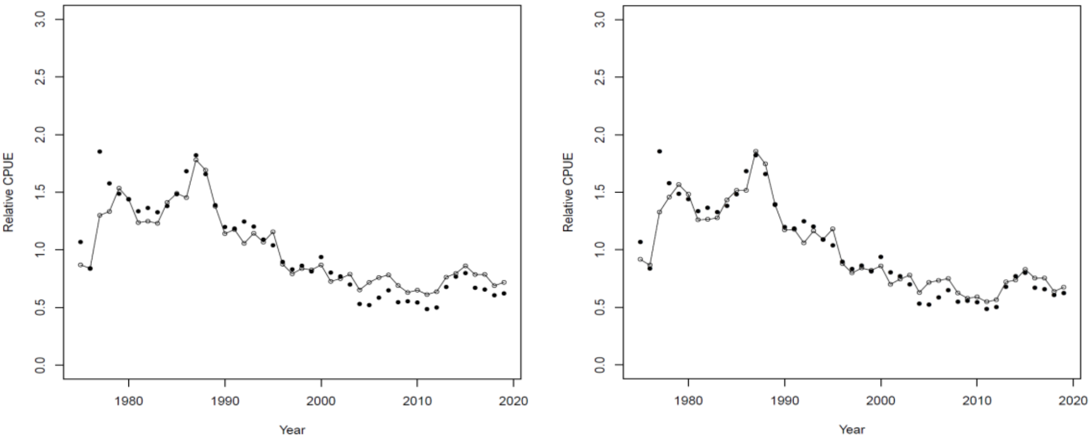


Figure 4. Species composition for each cluster by fleet.

(R1)



(R2)



(R3)

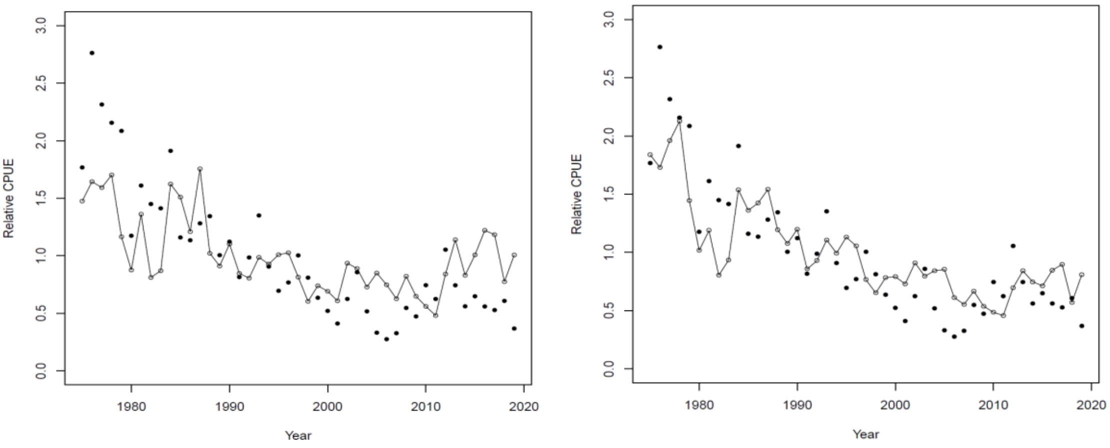
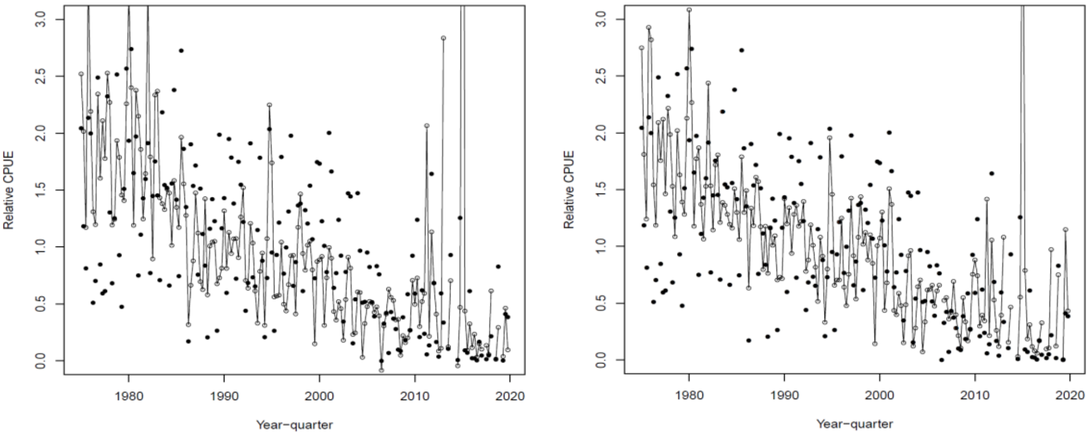
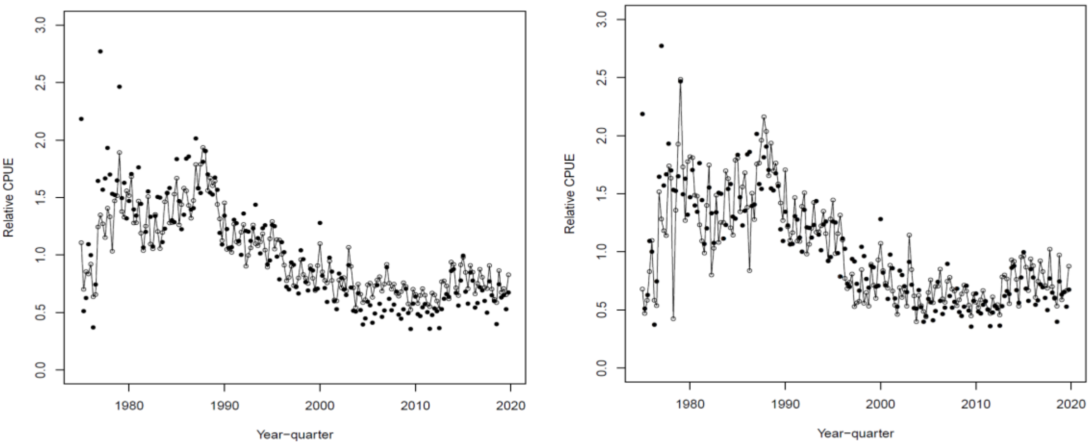


Figure 5. Nominal (black circles) and estimated annual indices (line with open circles) from the LN (left) and DL (right) annual models.

(R1)



(R2)



(R3)

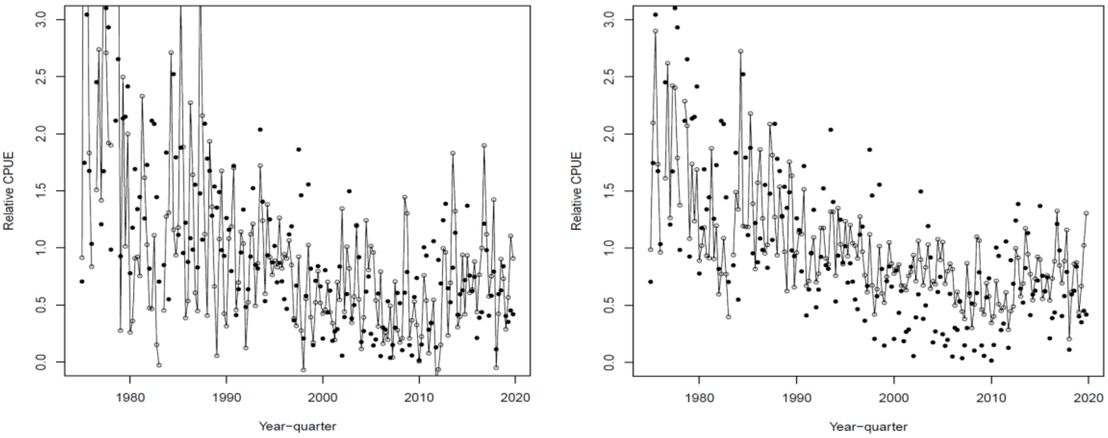


Figure 6. Nominal (black circles) and estimated annual indices (line with open circles) from the LN (left) and DL (right) quarterly models. The adjustment factor c=1% was used for R1 and R3 to avoid producing negative indices.

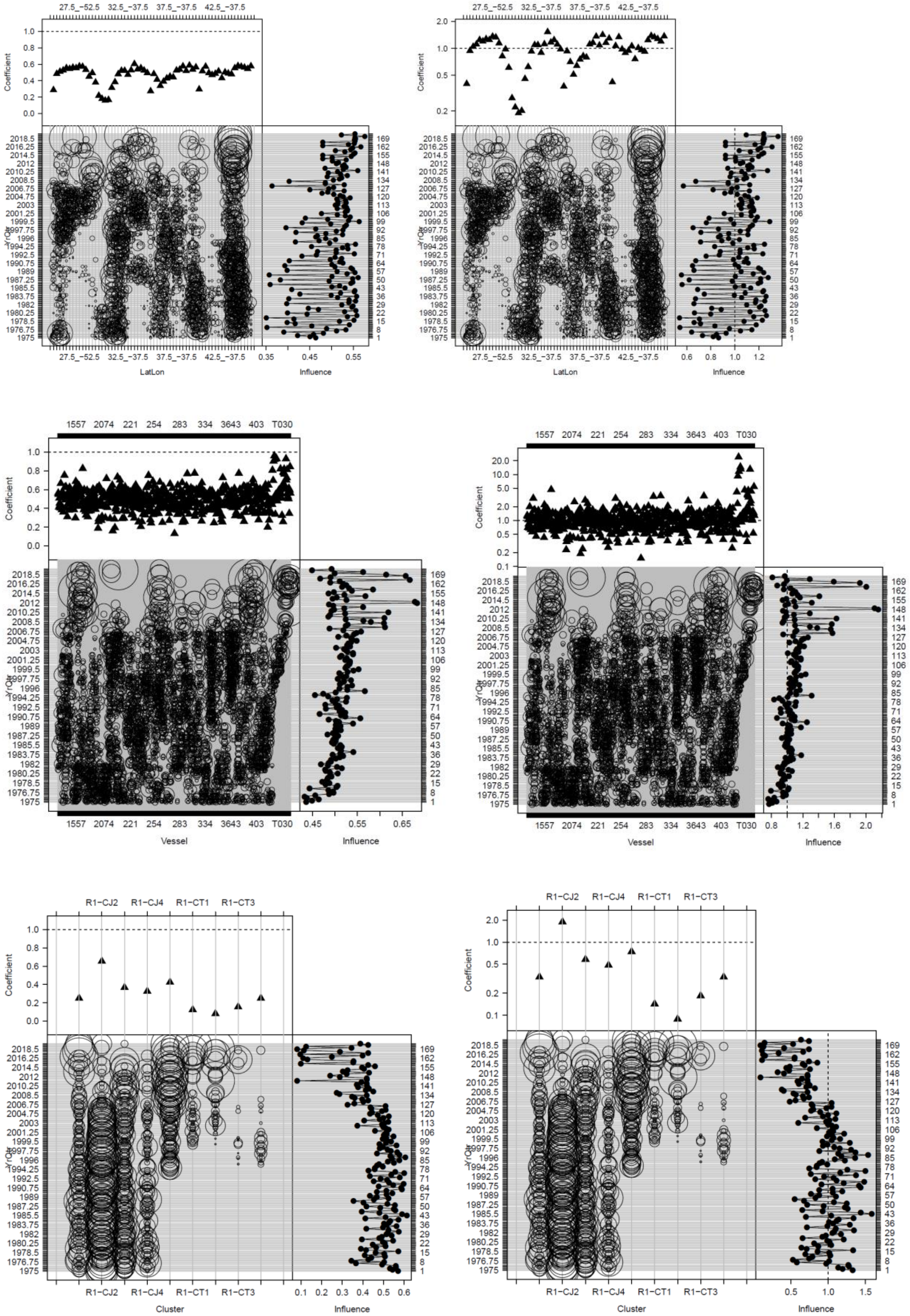


Figure 7-1. Example influence plots for delta (left) and positive catch (right) components for the quarterly DL model in Region 1.

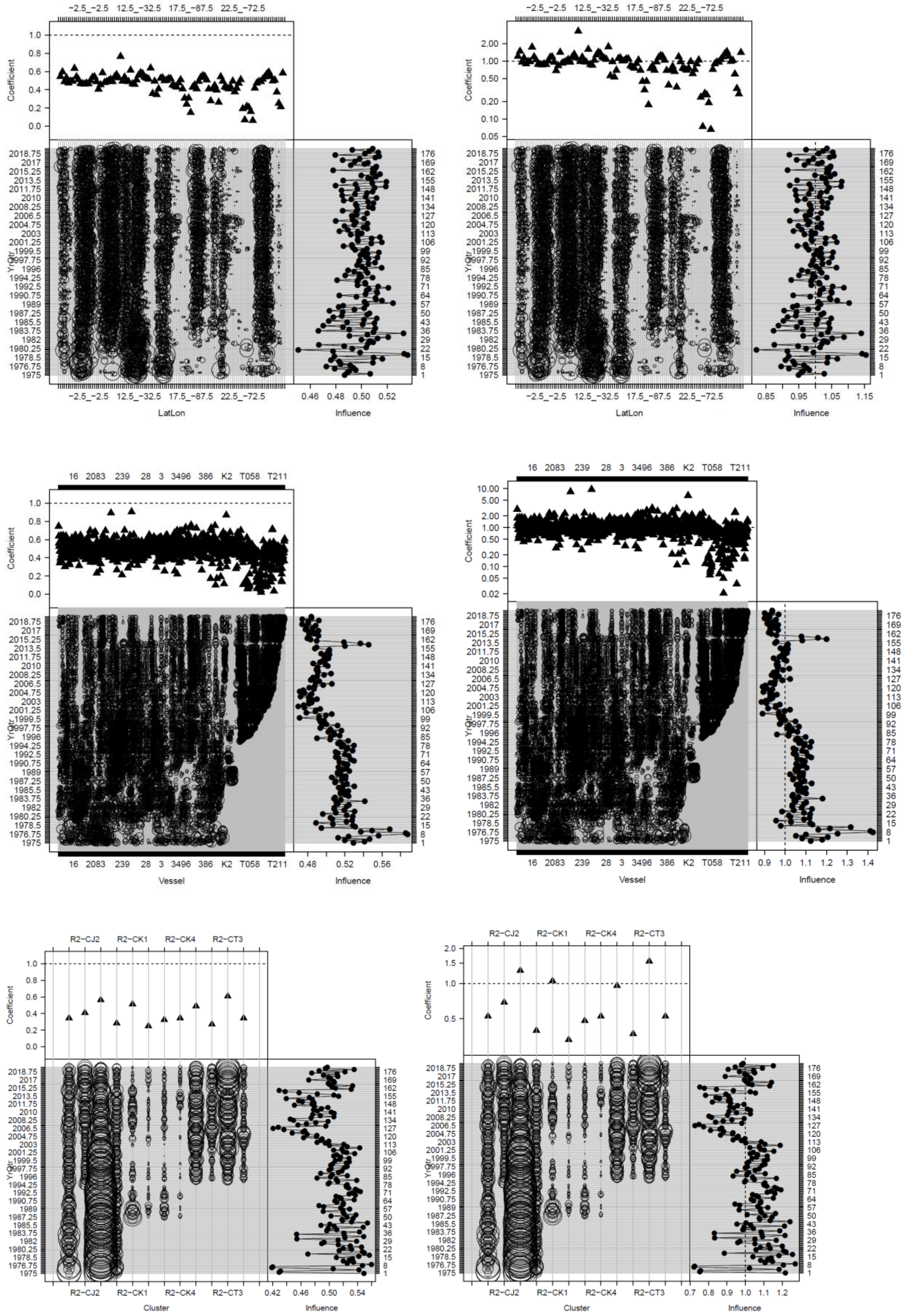


Figure 7-2. Example influence plots for delta (left) and positive catch (right) components for the quarterly DL model in Region 2.

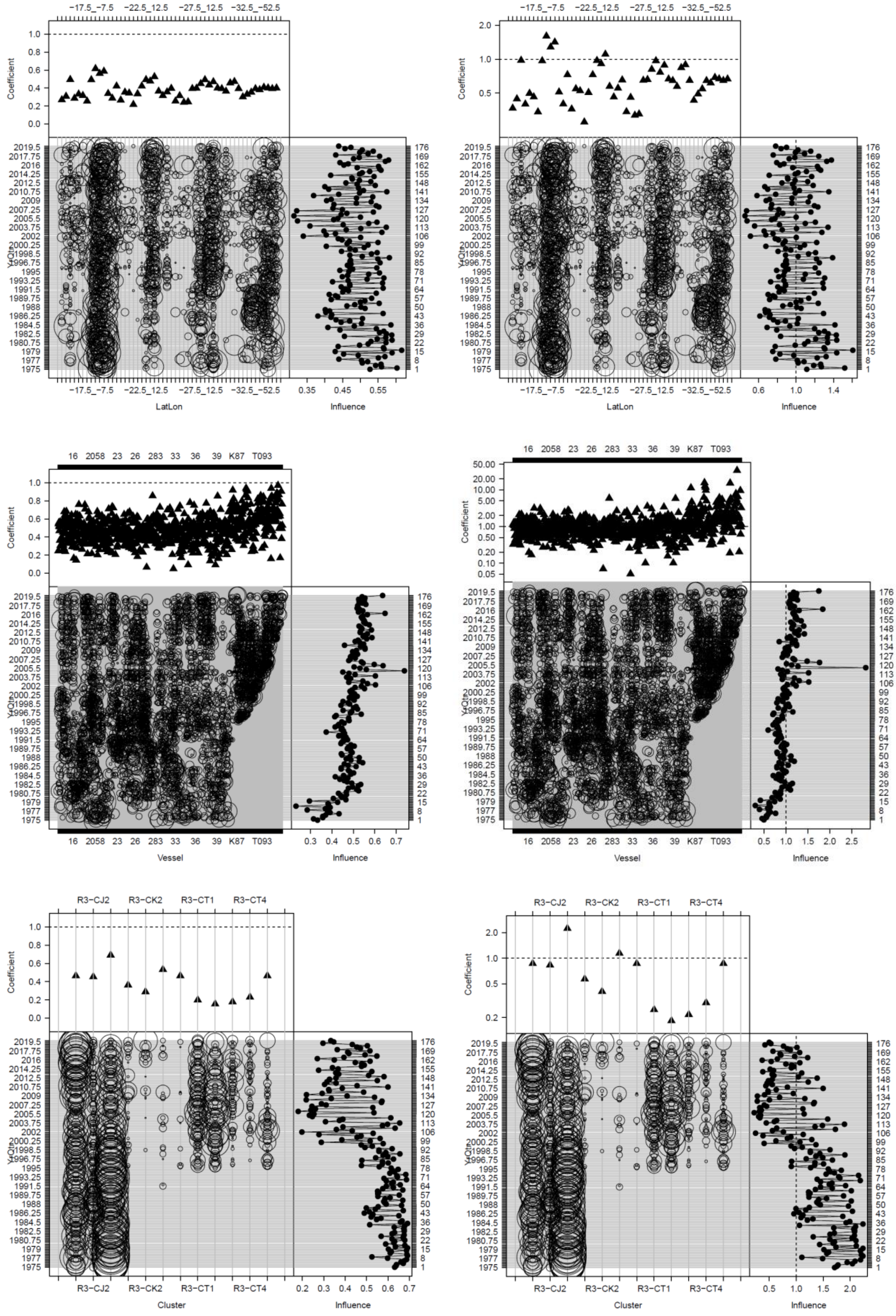


Figure 7-3: Example influence plots for delta (left) and positive catch (right) components for the quarterly DL model in Region 3.

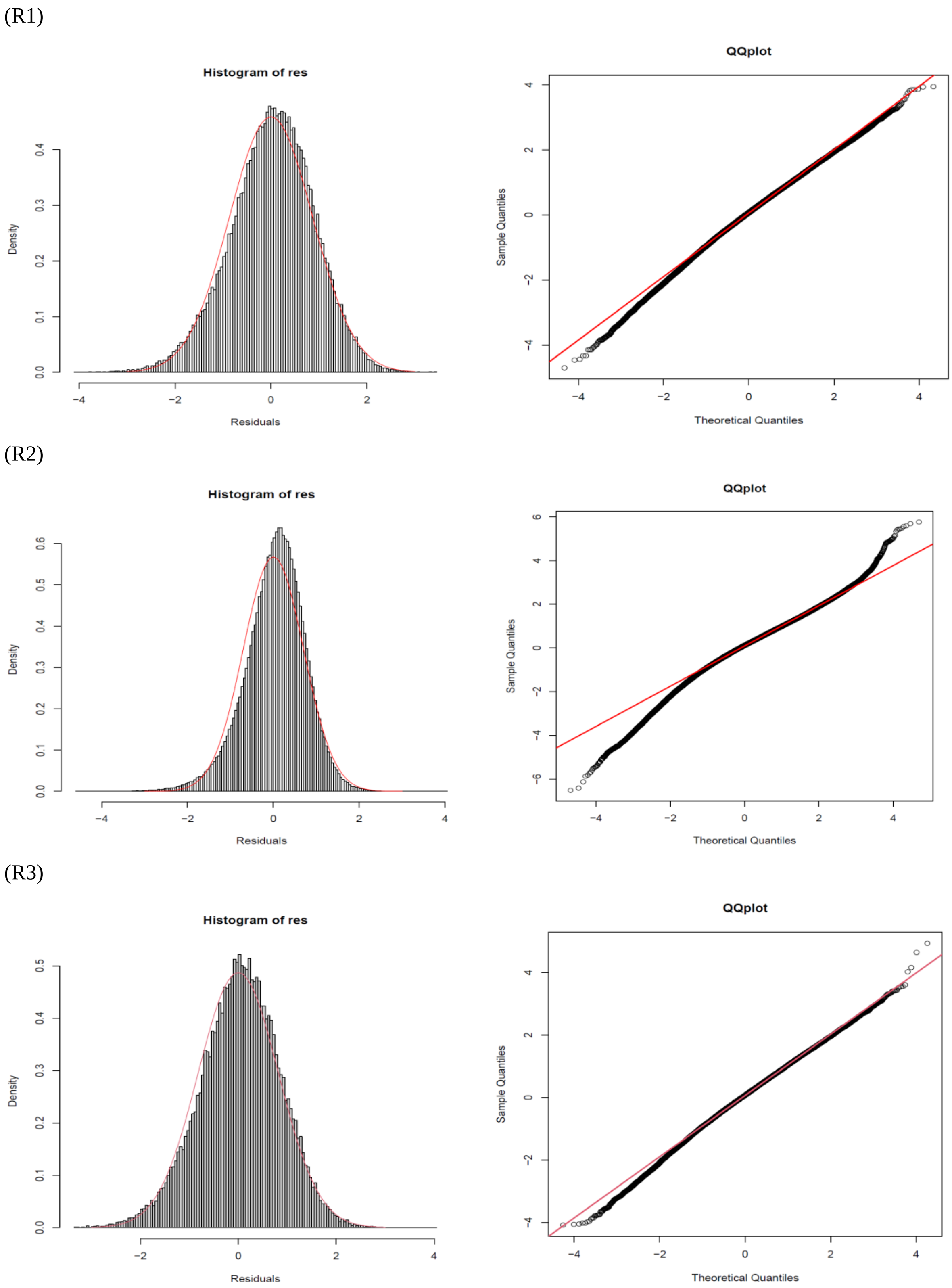


Figure 8. Residual and Q-Q plots for the positive catch component in the quarterly DL model.

Region 2 for Quarterly LN model with c=10% **Region 2 for Quarterly LN model with c=1%**

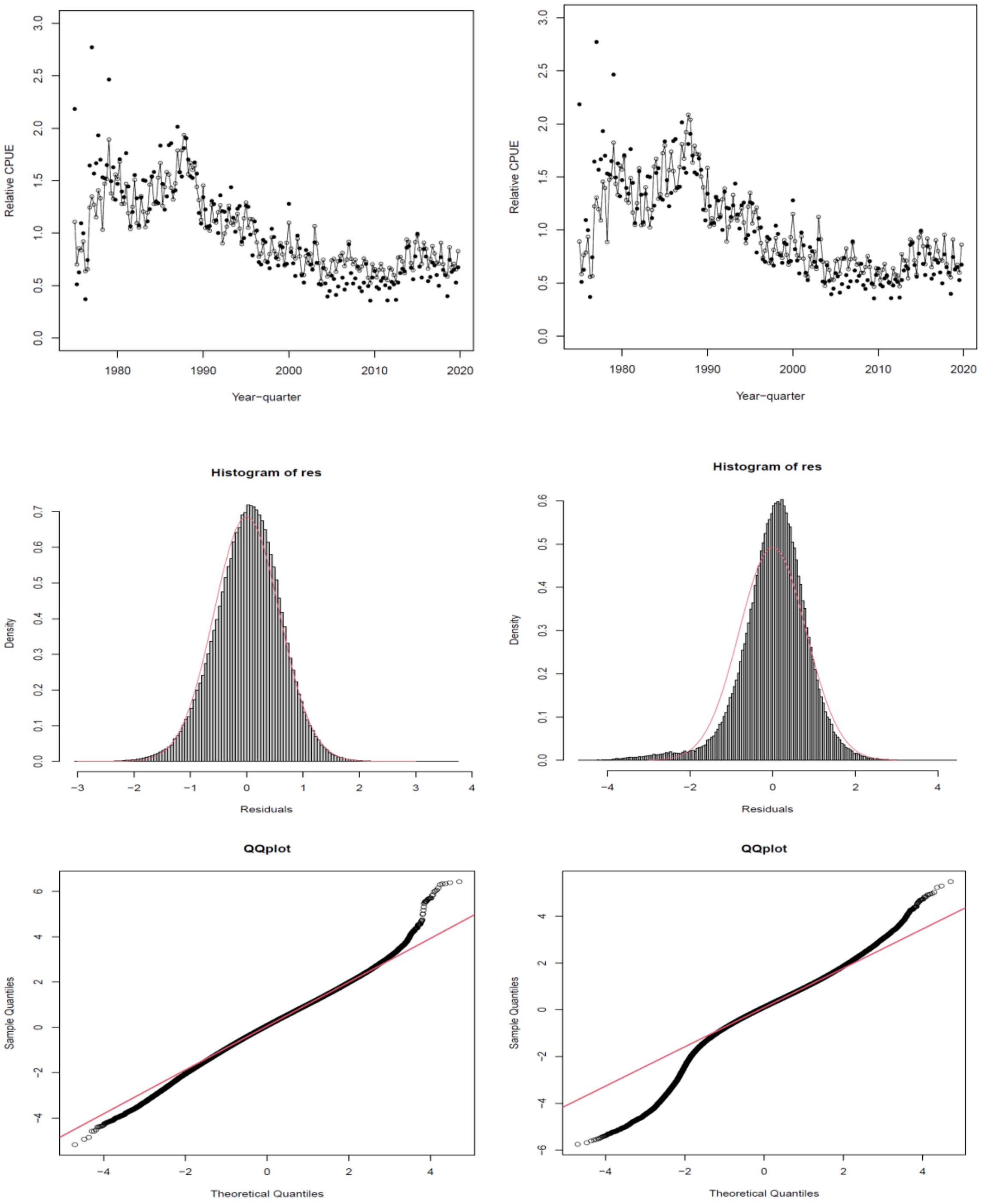


Figure 9. Example plots for the effects of different adjustment factors (c=10% and 1%) for the LN quarterly model in Region 2.

Appendix 1

Final estimates (Annual)

Year	R1_Est	R1_CV	R2_Est	R2_CV	R3_Est	R3_CV
1975	1.7683	0.0646	0.8164	0.0411	1.4753	0.0891
1976	1.4724	0.0689	0.9611	0.0439	1.6443	0.1078
1977	1.6644	0.0692	1.4886	0.0421	1.5930	0.0914
1978	1.5594	0.0707	1.2554	0.0450	1.7023	0.1053
1979	1.8532	0.0699	1.5554	0.0441	1.1656	0.1189
1980	1.9501	0.0675	1.5047	0.0385	0.8765	0.0951
1981	1.3453	0.0692	1.2595	0.0370	1.3619	0.0824
1982	1.6999	0.0708	1.2784	0.0356	0.8117	0.0934
1983	1.7934	0.0710	1.2536	0.0379	0.8705	0.1198
1984	1.6801	0.0728	1.4690	0.0356	1.6233	0.1035
1985	1.4388	0.0732	1.5482	0.0341	1.5100	0.0778
1986	0.9103	0.0910	1.4621	0.0357	1.2097	0.0862
1987	1.1398	0.0785	1.8447	0.0347	1.7559	0.0813
1988	0.9922	0.0829	1.7340	0.0344	1.0216	0.0820
1989	0.9037	0.0839	1.4165	0.0345	0.9116	0.0873
1990	1.2896	0.0768	1.1817	0.0357	1.1028	0.0795
1991	1.1102	0.0785	1.1973	0.0354	0.8471	0.0808
1992	1.0730	0.0805	1.0599	0.0369	0.8063	0.0860
1993	0.8300	0.0923	1.1824	0.0361	0.9867	0.0844
1994	1.0138	0.0903	1.0921	0.0365	0.9280	0.0776
1995	0.9813	0.0864	1.2155	0.0354	1.0096	0.0731
1996	0.8711	0.0889	0.8509	0.0374	1.0260	0.0754
1997	1.0421	0.0839	0.7575	0.0382	0.8148	0.0868
1998	1.1333	0.0771	0.7928	0.0384	0.6047	0.0953
1999	0.8930	0.0893	0.7757	0.0383	0.7400	0.0857
2000	0.9738	0.0801	0.7900	0.0379	0.6918	0.0822
2001	0.8421	0.0832	0.6555	0.0398	0.6092	0.0890
2002	0.5820	0.1113	0.6995	0.0390	0.9361	0.0784
2003	0.7477	0.0932	0.7195	0.0384	0.8894	0.0826
2004	0.5342	0.1213	0.5802	0.0404	0.7287	0.0844
2005	0.6752	0.0935	0.6732	0.0388	0.8503	0.0863
2006	0.4263	0.1895	0.7457	0.0385	0.7484	0.0860
2007	0.7477	0.1303	0.7554	0.0387	0.6271	0.0981
2008	0.4464	0.1448	0.6429	0.0402	0.8224	0.0927
2009	0.4091	0.1744	0.5757	0.0412	0.6485	0.0930
2010	0.7405	0.1248	0.6097	0.0407	0.5606	0.0953
2011	0.7475	0.1842	0.5852	0.0405	0.4815	0.0961
2012	0.5831	0.2072	0.6235	0.0402	0.8415	0.0809
2013	1.0155	0.1901	0.7870	0.0387	1.1392	0.0745
2014	0.3408	0.2986	0.8354	0.0397	0.8311	0.0835
2015	1.2336	0.1465	0.8568	0.0388	1.0080	0.0831
2016	0.2449	0.3866	0.7856	0.0394	1.2213	0.0823
2017	0.2632	0.4579	0.7623	0.0394	1.1836	0.0824
2018	0.7130	0.1695	0.6572	0.0412	0.7751	0.0902
2019	0.3247	0.3712	0.7064	0.0397	1.0073	0.0800

Appendix 2

Final estimates (Quarterly)

Year	Quarter	R1_Est	R1_CV	R2_EST	R2_CV	R3_EST	R2_CV
1975	1	2.7466	NA	0.9438	0.0395	0.9871	NA
1975	2	1.8109	NA	0.6888	0.0426	2.0965	NA
1975	3	1.2408	NA	0.7741	0.0385	2.8998	NA
1975	4	2.9278	NA	0.8494	0.0438	1.7343	NA
1976	1	2.8179	NA	0.9409	0.0454	0.9646	NA
1976	2	1.5427	NA	0.6795	0.0441		NA
1976	3	1.1834	NA	0.6944	0.0433	1.6117	NA
1976	4	2.0878	NA	1.7594	0.0445	2.6177	NA
1977	1	1.7560	NA	1.7133	0.0439	1.2649	NA
1977	2	2.1196	NA	1.2983	0.0457	2.4219	NA
1977	3	1.4604	NA	1.1985	0.0402	2.4035	NA
1977	4	2.2154	NA	1.7695	0.0392	1.7900	NA
1978	1	1.9839	NA	1.1369	0.0445	1.3766	NA
1978	2	1.5287	NA	0.9489	0.0491		NA
1978	3	1.0865	NA	1.4979	0.0404	2.2860	NA
1978	4	2.0182	NA	1.4710	0.0466	2.0709	NA
1979	1	1.6272	NA	1.7137	0.0538	1.0835	NA
1979	2	1.3898	NA	1.5017	0.0414	1.7363	NA
1979	3	1.2827	NA	1.3743	0.0405	1.2370	NA
1979	4	2.1283	NA	1.5997	0.0405	1.6875	NA
1980	1	3.0810	NA	1.5809	0.0402	0.8912	NA
1980	2	2.2640	NA	1.8459	0.0371	1.0226	NA
1980	3	1.1786	NA	1.3366	0.0385	1.1810	NA
1980	4	1.7693	NA	1.2650	0.0383	0.9352	NA
1981	1	1.8668	NA	1.4235	0.0373	0.9135	NA
1981	2	1.3686	NA	1.2214	0.0372	1.8733	NA
1981	3	1.0651	NA	1.0549	0.0385	0.9067	NA
1981	4	1.5269	NA	1.3234	0.0352	1.1965	NA
1982	1	2.4376	NA	1.5997	0.0339	0.5975	NA
1982	2	1.5325	NA	1.1223	0.0363	0.7747	NA
1982	3	1.1438	NA	1.0398	0.0378	1.0873	NA
1982	4	1.7150	NA	1.3733	0.0348	0.7728	NA
1983	1	1.8043	NA	1.1623	0.0367	0.3994	NA
1983	2	1.2109	NA	1.0849	0.0435		NA
1983	3	1.3853	NA	1.2546	0.0374	0.9409	NA
1983	4	1.3591	NA	1.5045	0.0346	1.4900	NA
1984	1	1.2835	NA	1.6126	0.0347	1.3399	NA
1984	2	1.1937	NA	1.2999	0.0378	2.7232	NA
1984	3	1.1617	NA	1.3201	0.0363	1.1933	NA
1984	4	1.5060	NA	1.6245	0.0340	1.1869	NA
1985	1	1.2976	NA	1.7374	0.0346	1.1857	NA
1985	2	1.0588	NA	1.2939	0.0349	2.1780	NA
1985	3	1.7866	NA	1.4802	0.0340	1.3895	NA
1985	4	1.2984	NA	1.6661	0.0330	0.8183	NA
1986	1	1.4917	NA	1.5582	0.0359	1.5724	NA
1986	2	0.6333	NA	1.3820	0.0370	1.8627	NA
1986	3	1.3376	NA	1.3176	0.0355	1.2609	NA
1986	4	1.1819	NA	1.5571	0.0346	0.9558	NA
1987	1	1.6063	NA	1.8650	0.0344	1.0296	NA
1987	2	1.5716	NA	1.6530	0.0354	2.0856	NA
1987	3	1.1728	NA	1.7585	0.0352	1.8140	NA
1987	4	0.7941	NA	2.0655	0.0339	1.2731	NA
1988	1	1.1752	NA	2.0348	0.0352	0.9389	NA
1988	2	0.7614	NA	1.6034	0.0344	1.5374	NA
1988	3	1.1635	NA	1.6397	0.0339	1.2757	NA
1988	4	1.0074	NA	1.6328	0.0339	0.9687	NA
1989	1	1.0921	NA	1.7657	0.0342	0.6253	NA
1989	2	0.7023	NA	1.4707	0.0340	1.7556	NA
1989	3	0.7283	NA	1.3077	0.0350	1.6335	NA
1989	4	0.7180	NA	1.1395	0.0353	0.6590	NA
1990	1	1.4178	NA	1.4879	0.0353	0.9613	NA
1990	2	1.1963	NA	1.1088	0.0358	1.1380	NA
1990	3	1.3400	NA	1.0705	0.0358	1.1247	NA
1990	4	0.9378	NA	1.0626	0.0363	1.5152	NA

Appendix 2 (continued)

Year	Quarter	R1_Est	R1_CV	R2_EST	R2_CV	R3_EST	R2_CV
1991	1	1.2794	NA	1.2872	0.0355	0.6722	NA
1991	2	1.3630	NA	1.1608	0.0356	0.7133	NA
1991	3	1.1767	NA	1.1384	0.0352	0.9552	NA
1991	4	1.2169	NA	1.1691	0.0355	1.0946	NA
1992	1	1.3949	NA	1.2919	0.0354	0.7033	NA
1992	2	0.7811	NA	0.8677	0.0393	0.7774	NA
1992	3	0.8776	NA	1.0019	0.0365	1.1776	NA
1992	4	1.1908	NA	1.0798	0.0368	1.1768	NA
1993	1	1.0083	NA	1.2605	0.0363	0.9103	NA
1993	2	0.8175	NA	1.1798	0.0364	0.8600	NA
1993	3	0.5165	NA	1.1277	0.0362	1.3196	NA
1993	4	1.0795	NA	1.1278	0.0356	1.3181	NA
1994	1	0.9129	NA	1.2222	0.0370	0.7599	NA
1994	2	0.3320	NA	1.1004	0.0367	1.3504	NA
1994	3	0.8018	NA	0.8971	0.0370	1.0339	NA
1994	4	1.9569	NA	1.1360	0.0354	0.8612	NA
1995	1	1.4577	NA	1.3878	0.0349	1.2357	NA
1995	2	0.6569	NA	1.1205	0.0359	0.9315	NA
1995	3	0.7057	NA	1.1952	0.0354	1.2033	NA
1995	4	0.7053	NA	1.1347	0.0352	1.0439	NA
1996	1	1.2498	NA	0.9513	0.0365	1.0228	NA
1996	2	0.6414	NA	0.9191	0.0372	0.9111	NA
1996	3	0.4761	NA	0.7688	0.0380	1.2765	NA
1996	4	0.7553	NA	0.7516	0.0379	0.9698	NA
1997	1	1.4239	NA	0.8846	0.0375	0.7631	NA
1997	2	0.9186	NA	0.7040	0.0389	0.6152	NA
1997	3	0.5348	NA	0.6880	0.0388	1.1212	NA
1997	4	1.0808	NA	0.7408	0.0378	0.6746	NA
1998	1	1.4363	NA	0.8950	0.0384	0.4208	NA
1998	2	1.0163	NA	0.8185	0.0386	0.6421	NA
1998	3	1.1241	NA	0.7480	0.0382	1.0178	NA
1998	4	0.8796	NA	0.6954	0.0386	0.6050	NA
1999	1	1.1016	NA	0.8924	0.0378	0.5233	NA
1999	2	0.8508	NA	0.7326	0.0387	0.7508	NA
1999	3	0.1428	NA	0.6420	0.0400	1.0502	NA
1999	4	1.0059	NA	0.8290	0.0372	0.8661	NA
2000	1	1.0721	NA	1.0346	0.0355	0.7783	NA
2000	2	1.3015	NA	0.7739	0.0377	0.8214	NA
2000	3	0.4380	NA	0.7057	0.0391	0.8571	NA
2000	4	0.6797	NA	0.6585	0.0398	0.6743	NA
2001	1	1.5056	NA	0.8873	0.0368	0.6710	NA
2001	2	1.3686	NA	0.7229	0.0388	0.6334	NA
2001	3	0.4349	NA	0.5306	0.0424	0.7581	NA
2001	4	0.3977	NA	0.5109	0.0428	0.7931	NA
2002	1	0.5870	NA	0.7555	0.0381	0.9388	NA
2002	2	0.4761	NA	0.6596	0.0393	0.7126	NA
2002	3	0.1515	NA	0.7675	0.0386	1.0638	NA
2002	4	0.4846	NA	0.6032	0.0405	0.9006	NA
2003	1	0.9171	NA	0.9798	0.0357	0.6755	NA
2003	2	0.9620	NA	0.8635	0.0368	0.8326	NA
2003	3	0.1208	NA	0.6657	0.0389	1.0318	NA
2003	4	0.2815	NA	0.4389	0.0448	0.6465	NA
2004	1	0.6434	NA	0.6696	0.0389	0.7118	NA
2004	2	0.7035	NA	0.5989	0.0396	0.6851	NA
2004	3	0.0704	NA	0.5150	0.0416	1.0782	NA
2004	4	0.3342	NA	0.5281	0.0418	0.8982	NA
2005	1	0.6170	NA	0.6764	0.0387	1.0531	NA
2005	2	0.6203	NA	0.7284	0.0379	0.6894	NA
2005	3	0.6580	NA	0.5974	0.0396	0.7984	NA
2005	4	0.4741	NA	0.6738	0.0390	0.8627	NA

Appendix 2 (continued)

Year	Quarter	R1_Est	R1_CV	R2_EST	R2_CV	R3_EST	R2_CV
2006	1	0.6075	NA	0.7382	0.0385	0.8174	NA
2006	2	0.6588	NA	0.8303	0.0370	0.5004	NA
2006	3		NA	0.6826	0.0392	0.6176	NA
2006	4	0.5257	NA	0.7138	0.0396	0.5372	NA
2007	1	0.5497	NA	0.8818	0.0378	0.4459	NA
2007	2	0.3600	NA	0.7688	0.0386	0.3813	NA
2007	3	0.4207	NA	0.6821	0.0392	0.8683	NA
2007	4	0.6892	NA	0.6782	0.0394	0.5834	NA
2008	1	0.3999	NA	0.5647	0.0428	0.3025	NA
2008	2	0.2143	NA	0.6258	0.0399	0.5082	NA
2008	3	0.1037	NA	0.6446	0.0393	1.1003	NA
2008	4	0.5473	NA	0.7233	0.0390	1.0688	NA
2009	1	0.3359	NA	0.6499	0.0409	0.4630	NA
2009	2	0.1696	NA	0.5143	0.0420	0.4210	NA
2009	3	0.2731	NA	0.4714	0.0433	0.6941	NA
2009	4	0.7547	NA	0.6664	0.0393	0.5780	NA
2010	1	0.8809	NA	0.6043	0.0414	0.3466	NA
2010	2	0.7426	NA	0.5310	0.0419	0.4032	NA
2010	3	0.2974	NA	0.6089	0.0399	0.7136	NA
2010	4	0.3940	NA	0.6820	0.0398	0.5107	NA
2011	1	0.3456	NA	0.5903	0.0409	0.4529	NA
2011	2	1.4149	NA	0.5472	0.0413	0.4815	NA
2011	3	0.2159	NA	0.5332	0.0414	0.6130	NA
2011	4	1.0569	NA	0.6568	0.0388	0.2872	NA
2012	1	0.5292	NA	0.6171	0.0404	0.4503	NA
2012	2	0.2589	NA	0.5986	0.0403	0.4899	NA
2012	3	0.1192	NA	0.4906	0.0430	0.9991	NA
2012	4	0.3958	NA	0.7945	0.0378	0.9168	NA
2013	1	1.0799	NA	0.7772	0.0383	0.5784	NA
2013	2		NA	0.7463	0.0391	0.6916	NA
2013	3	0.1573	NA	0.6325	0.0409	1.1744	NA
2013	4	0.4653	NA	1.0003	0.0370	0.9483	NA
2014	1		NA	0.9399	0.0385	0.7743	NA
2014	2		NA	0.7807	0.0392	0.5455	NA
2014	3	0.0306	NA	0.6469	0.0426	0.7336	NA
2014	4	0.5521	NA	0.9814	0.0392	0.9251	NA
2015	1	5.3492	NA	0.9750	0.0391	0.9013	NA
2015	2	0.7893	NA	0.9015	0.0379	0.5576	NA
2015	3	0.1835	NA	0.6518	0.0407	0.6242	NA
2015	4	0.3103	NA	0.9012	0.0379	0.7611	NA
2016	1	0.1164	NA	0.8268	0.0396	0.5438	NA
2016	2	0.0796	NA	0.6981	0.0398	0.7355	NA
2016	3	0.0583	NA	0.7465	0.0398	0.8862	NA
2016	4	0.1735	NA	0.8536	0.0384	1.3255	NA
2017	1	0.3278	NA	0.8016	0.0397	0.8489	NA
2017	2		NA	0.7010	0.0401	0.6941	NA
2017	3	0.0953	NA	0.6550	0.0404	0.8871	NA
2017	4	0.1057	NA	0.8827	0.0378	1.1597	NA
2018	1	0.9700	NA	0.6684	0.0409	0.2058	NA
2018	2		NA	0.5775	0.0431	0.6183	NA
2018	3	0.1204	NA	0.5479	0.0438	0.8628	NA
2018	4	0.7485	NA	0.8419	0.0379	0.8757	NA
2019	1		NA	0.6276	0.0413	0.4406	NA
2019	2	0.0000	NA	0.7086	0.0400	0.6683	NA
2019	3	1.1471	NA	0.6382	0.0400	1.0248	NA
2019	4	0.4298	NA	0.8436	0.0378	1.3063	NA