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Standardizations of Taiwanese distant-water longline CPUE up to 2010 for yellowfin and bigeye tunas in Region 6 of WCPO

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Abstract

Taiwanese distant water longline fishery has operated throughout the WCPO since the 1960s with the following target species: northern albacore in Regions 1 and 2 of the WCPO, bigeye and yellowfin in Regions 3 and 4, and southern albacore in Regions 5 and 6. Among the regions, fishing operations in Region 6 have the most complete time series of data, with more consistent fishing activity and species targeting than indices available from other distant water fishing nations. It is therefore considered important to obtain standardized CPUE series for this fleet and region, which may then be used in the stock assessments of WCPO yellowfin and bigeye tunas. This report provides standardized CPUE series for the two species in the region using a delta-lognormal approach. Factors affecting catch rates are investigated using regression tree methods.

1. Introduction

Taiwanese tuna fisheries have a long history of fishing in the Western and Central Pacific Ocean (WCPO). Records of longline fisheries are available as far back as the 1960s. As the longline fisheries developed, some vessels began to fish in the waters of coastal states of the WCPO in accordance with fishing access agreements. These vessels were termed the ‘offshore longline fishery’ and the rest, which constituted the majority of the effort, was termed the ‘distant-water longline fishery’ (DWLL). The DWLL provides about 45 years of fishing records since 1964.

Albacore, yellowfin and bigeye tunas have been the main species caught, but the approach to targeting has varied through time, as well as spatially. Each species has its main fishing ground in the Pacific: temperate waters in the north (Regions 1 and 2, Fig. 1) and the south (Regions 5 and 6) were the major fishing ground for albacore; and tropical waters (Regions 3 and 4) have been the major fishing ground for bigeye and yellowfin tunas.

Historically, DWLL vessels have consistently fished for southern albacore, especially in the Region 6 where there were few long-time series of fishing activities from other fishing fleets. Some of the vessels also fished for yellowfin to supply canneries in the early years (before mid-1970s) in tropical areas but later these activities have decreased due to market preference of albacore for canning. DWLL continued fishing for southern albacore. Recently, however, targeting of albacore has declined, with a reduction in the number of albacore vessels and shifting of target species to bigeye and yellowfin tunas, which currently have higher commercial value.

This target change was accompanied by many adaptations in the fishery, such as changes of fishing ground/season and fishing gear (e.g., number of hooks per basket). As may be expected, these changes affected the species-specific CPUE (catch per unit effort), and must be taken into account when using CPUE to develop an abundance index.

There are many other fishing fleets targeting yellowfin and bigeye tunas in the tropical area. Fisheries data from Regions 3 and 4 might be sufficient for stock assessment purposes. However, as mentioned above, Taiwanese DWLL has continuous fishing activities in Regions 5 and 6 and, comparing to other fishing fleets, can provide the most complete long time series of fisheries data from these regions, especially the Region 6. This report develops standardized CPUE series for the yellowfin and bigeye tunas in Region 6 using a delta-lognormal approach. Factors affecting catch rates are investigated using regression tree methods.

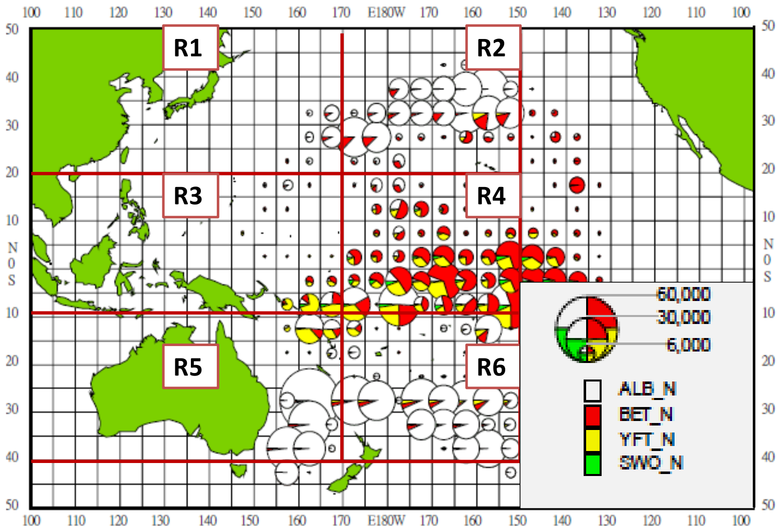

Fig. 1. Region stratification used in the study. The background is catch composition of Taiwanese DWLL in 2005 by the four major species: albacore (ALB), bigeye (BET), yellowfin (YFT) and swordfish (SWO), in terms of catch in number, by 5° by 5° square.

2. Materials and methods

Set by set logbook data of Taiwanese DWLL of 1964-2010 were obtained from the Overseas Fisheries Development Council of the ROC. These logbook data include vessel identity, fishing position (noon time position at 5°×5° longitude×latitude square level), fishing date, number of hooks deployed, catches (in number) of major tunas and billfishes (Fig. 1). The catch data have undergone a crosscheck process with commercial trading data on a trip-by-trip basis, since the detail commercial trading data became available in 1997. The fishing location information has undergone a similar verification process with VMS data, since 2005 when VMS data became reasonably complete. CPUE was calculated as catch in number per 1,000 hooks. The data from 2009-10 are still preliminary.

The logbook has also included information on number of hooks per basket (hpb) but starting from 1995. SST and 'bait used' information is also available since 1981 but the coverage was low (<50%) until recent years.

Change of target species has substantial effect on the process of CPUE standardization. When target species changes, many operation patterns may change to adapt to the preferred habitat features of that species. Regression tree methods (De'ath and Fabricius 2000) were used to investigate the factors affecting species-specific catch rates and to capture the possible operational changes based on as many available variables within the dataset. The available factors from the current dataset are: operation location (latitude and longitude), total hooks deployed, hpb, SST and bait type. Based on the study of Chang et al. (2011), a factor of vessel mode (velmode) was also developed from the spatial distribution of species composition – velmode=a for albacore vessels in the albacore areas (annual albacore catch ratio > 95% and fishing days in Regions 5 and 6 > 50%), velmode=b for albacore vessels in the yellowfin/bigeye areas (annual albacore catch ratio > 70% and fishing days in Regions 3 and 4 > 50%) and velmode=c for others (mainly the vessels fishing for yellowfin/bigeye).

Since information of these factors is more complete since 1995, data of 1995-2010 in Region 6 were used in the regression tree analyses. To have longest possible time series of data for the CPUE standardization, the first examination is to identify whether those variables are available for a limited number of years, such as hpb, SST and bait types, are significant or can be ignored. Since bigeye-targeting fishery was newly developed and has been intensively regulated by different staged management measures, the data might not be consistent internally and might change over time. Therefore, catch rate of yellowfin was used as the responding variable in the analyses. Using catch rate of albacore in this primarily albacore fishing ground as respondent variable was also tested.

Chang et al. (2011) have demonstrated that delta-lognormal model is more suitable for CPUE standardization on Taiwanese longline data with multi-target species. This report used the same model and includes factors of year (1964-2010), quarter (Jan.-Mar., Apr.-Jun., Jul.-Sep., and Oct.-Dec.), fishing location (5×5 square grid) and vessel identification code (vessel id). The vessel id was added in addition to previous analyses, because of the considerations that size and features of the vessel and skill of master may have effect on the catch rate. However the change of features (e.g. equipment) and masters through time could not be accounted for in this study.

3. Results and discussions

Regression tree analyses using yellowfin catch rate as respondent variable were firstly performed to investigate the factors affecting catch rates, and then based on the results CPUE standardizations were performed for yellowfin tuna and bigeye tuna separately. A regression tree analysis based on albacore catch rate was also conducted as a test. Since the result is difficult to interpret from the behavior of the fishery, no further CPUE standardization was conducted based on this result.

3.1 Regression tree analyses

Results of the regression tree analyses based on yellowfin catch rate are shown in Figs. 2 and 3. Both the two figures show that the most important classification factor is vessel mode: albacore vessels (velmod = a and b) can be the first group. For other vessels, hpb or latitude can be a good factor to separate them into additional two groups: the second group is hpb < 13.5 (supposedly albacore-targeting operation) or south of 25°S (the core albacore fishing ground); and the rest can be the third group. This result suggests that fishing location can replace the limit hpb information in this region and that the SST and bait type data can be ignored if they were not sufficient through time.

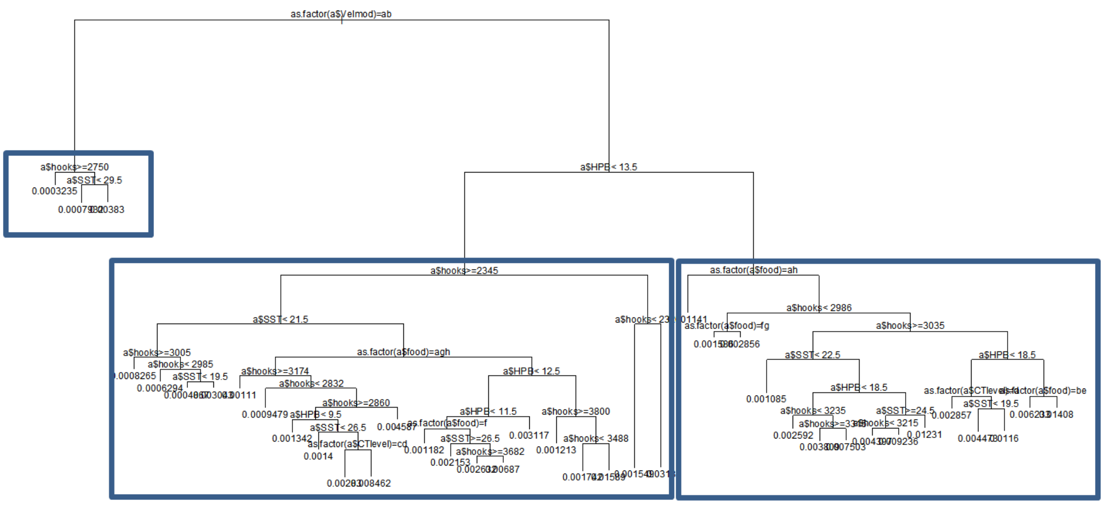

Fig. 2. Regression tree on yellowfin CPUE based on factors of hooks per basket information, total hooks deployed, SST, bait type and vessel mode. Operation location (latitude and longitude) was not included in this analysis.

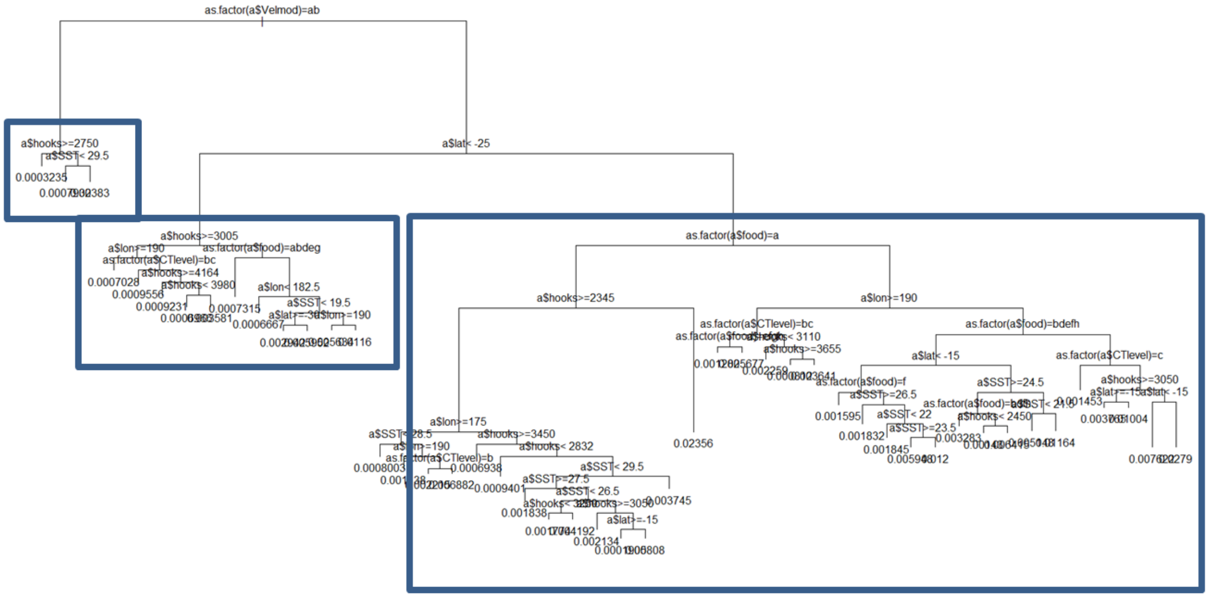

Fig. 3. Regression tree on yellowfin CPUE based on factors of operation location (latitude and longitude), total hooks deployed, SST, bait type and vessel mode. Hooks per basket information was not included in this study.

3.2 standardized CPUE series

3.2.1 Yellowfin tuna – residuals plot of GLM on positive catch rates and the CPUE series.

The residuals plot of GLM on positive catch rates and the CPUE series are shown in Figs. 4-6 for the three groups based on regression tree analyses, respectively.

Residuals of the three groups all showed good conformity with the lognormal assumption. An additional standardization run was therefore conducted on the combined dataset to develop a single index for this region. The residual distribution of GLM on positive CPUE and its CPUE series are shown in Fig. 7. ANOVA table is provided in Table 1 and the final delta-lognormal index is shown in Fig. 8. This index in Region 6 is recommended to be used for stock assessment of yellowfin tuna.

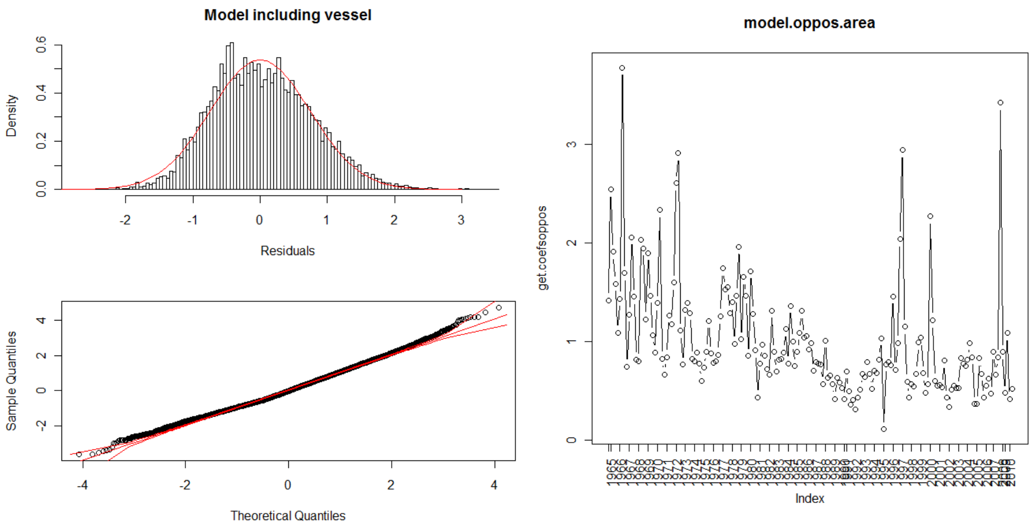

Fig. 4. Residuals plot of GLM on positive catch rates and the CPUE series of yellowfin tuna for the first group (albacore vessels) data.

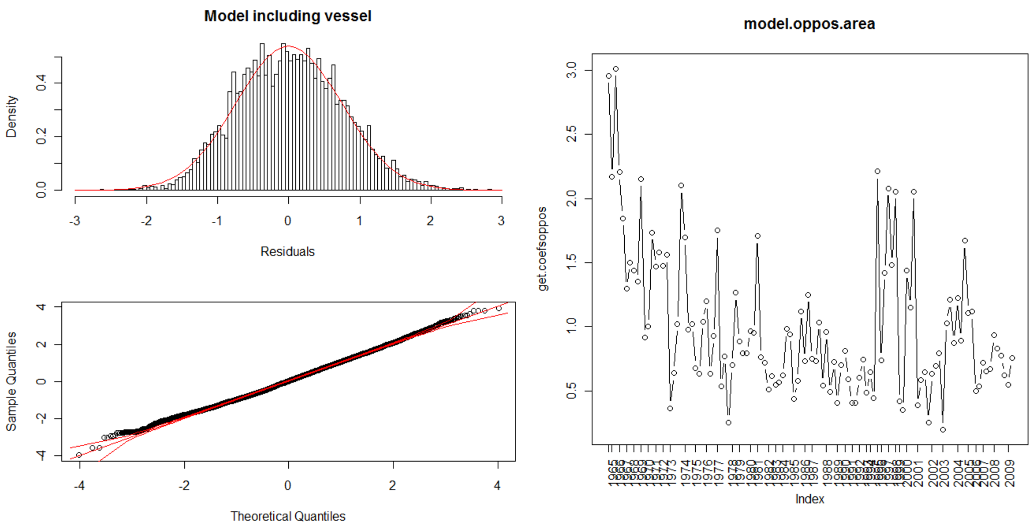

Fig. 5. Residuals plot of GLM on positive catch rates and the CPUE series of yellowfin tuna for the second group (YFT/BET vessels in north part of R6) data.

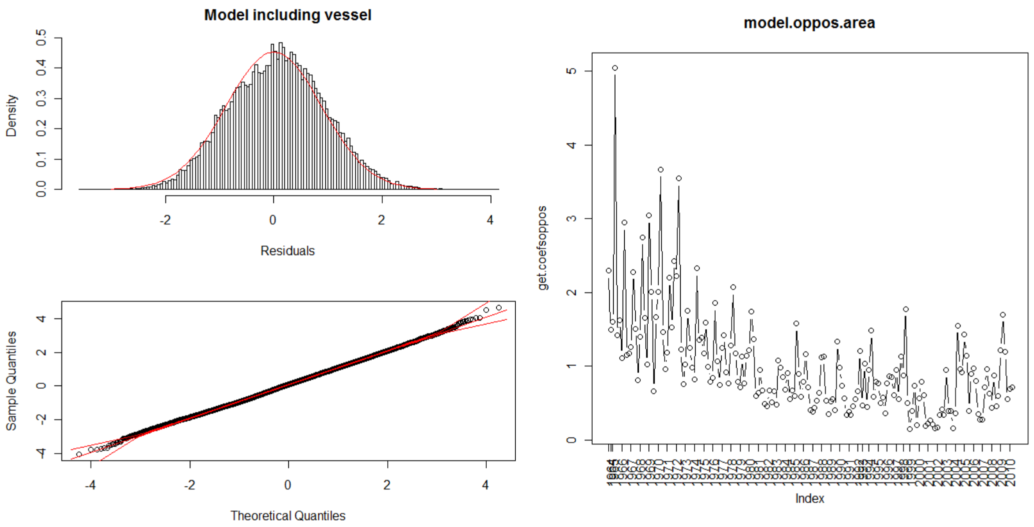

Fig. 6. Residuals plot of GLM on positive catch rates and the CPUE series of yellowfin tuna for the third group (YFT/BET vessels in core ALB fishing ground) data.

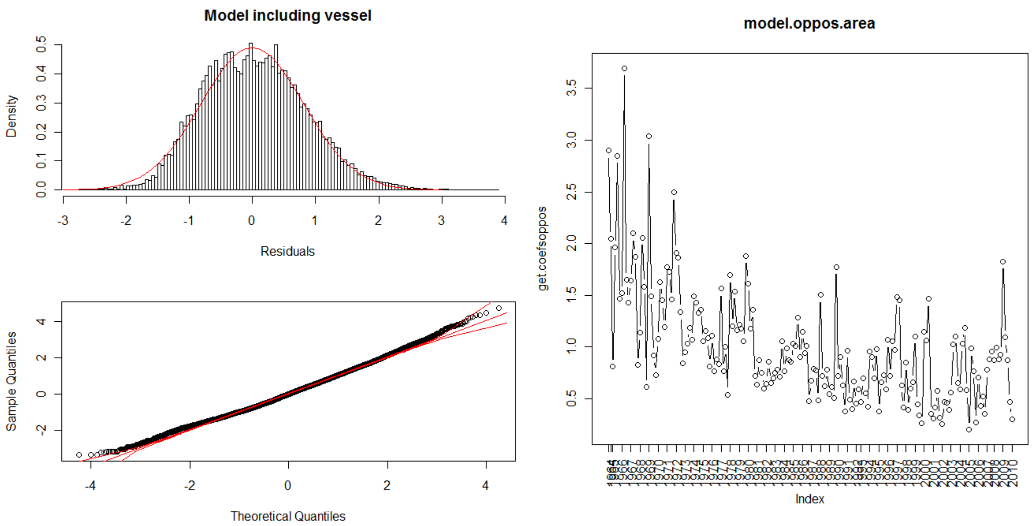

Fig. 7. Residuals plot of GLM on positive catch rates and the CPUE series of yellowfin tuna for combined dataset in Region 6.

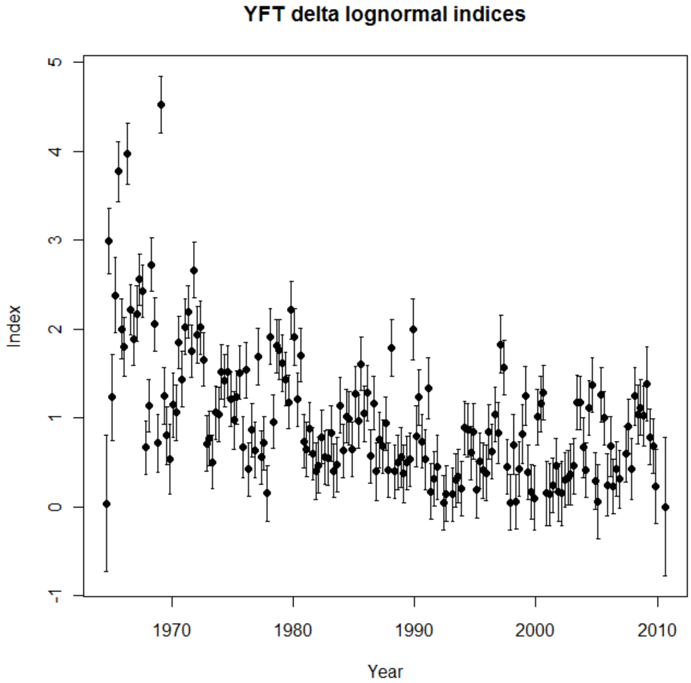

Fig. 8: Delta lognormal indices with 95% CIs (bars) for yellowfin tuna in region 6.

Table 1. ANOVA of the final standardization model for yellowfin tuna.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Year*Quarter	179	572.81	3.20	136.23	0.0000
Grid	38	161.59	4.25	181.02	0.0000
Vessel ID	578	217.38	0.37	16.01	0.0000
Residuals	46613	1094.97	0.02		

3.2.2 Bigeye tuna

Data were initially standardized bigeye catch rate by albacore targeting operations (the first group data). Residual performance was poor (Fig. 9). The two modes seen in the residuals may have been affected by yellowfin targeting operations in earlier years. These data need further investigation. Revising the definition of vessel mode from a yearly to a quarterly basis might also be helpful.

For the second group data (Fig. 10), residual performance is still marginal but better than for the analysis based on albacore vessels. For the third group data (Fig. 11), residual performance is poor, with two peaks indicating lack of conformity to model assumptions. Further investigations of the data are needed.

Since the residual distribution of the second group has better performance, result of this group is preferred for the stock assessment of bigeye tuna. Fig. 12 provides the final delta-lognormal index of Region 6 for this group and Table 2 provides the ANOVA table.

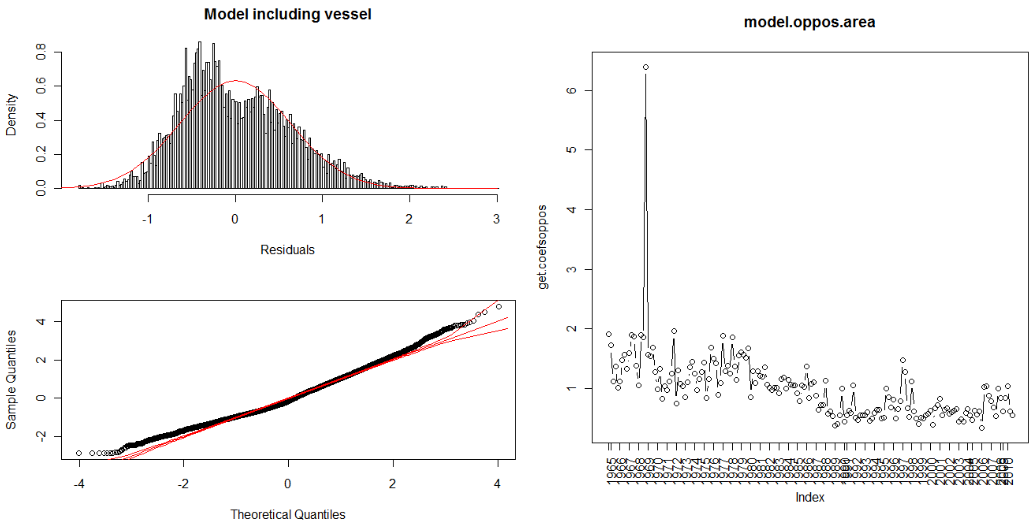

Fig. 9. Residuals plot of GLM on positive catch rates and the CPUE series of bigeye tuna for the first group (albacore vessels) data.

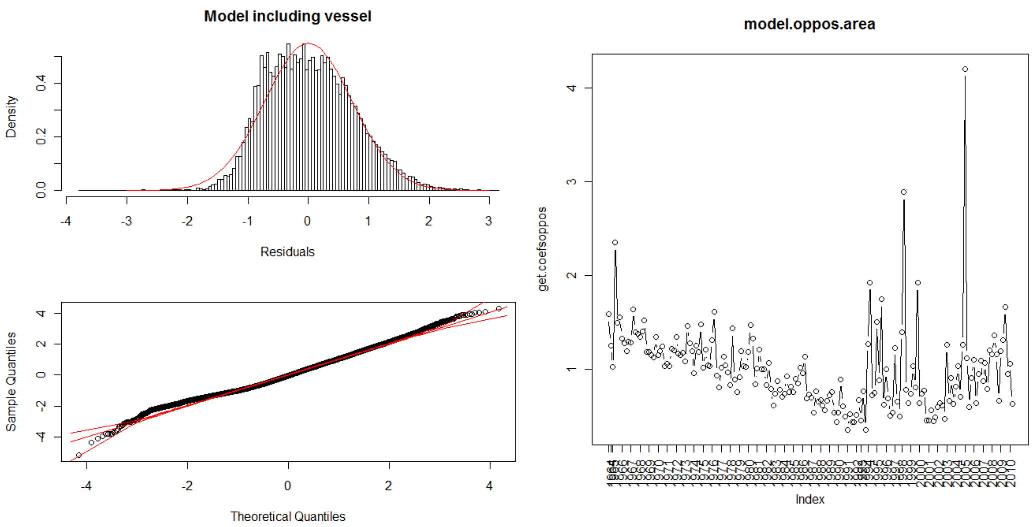

Fig. 10. Residuals plot of GLM on positive catch rates and the CPUE series of bigeye tuna for the second group (YFT/BET vessels in north part of R6) data.

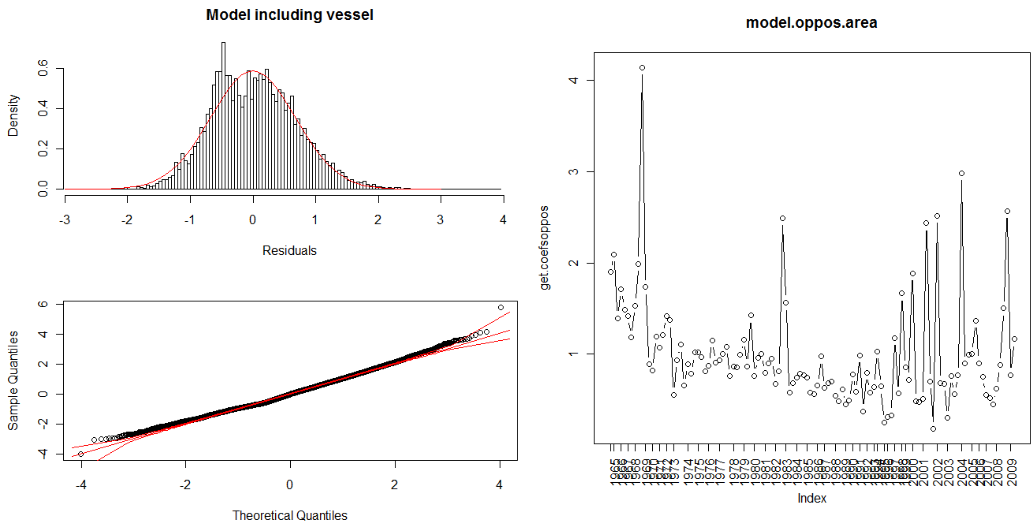

Fig. 11. Residuals plot of GLM on positive catch rates and the CPUE series of bigeye tuna for the third group (YFT/BET vessels in core ALB fishing ground) data.

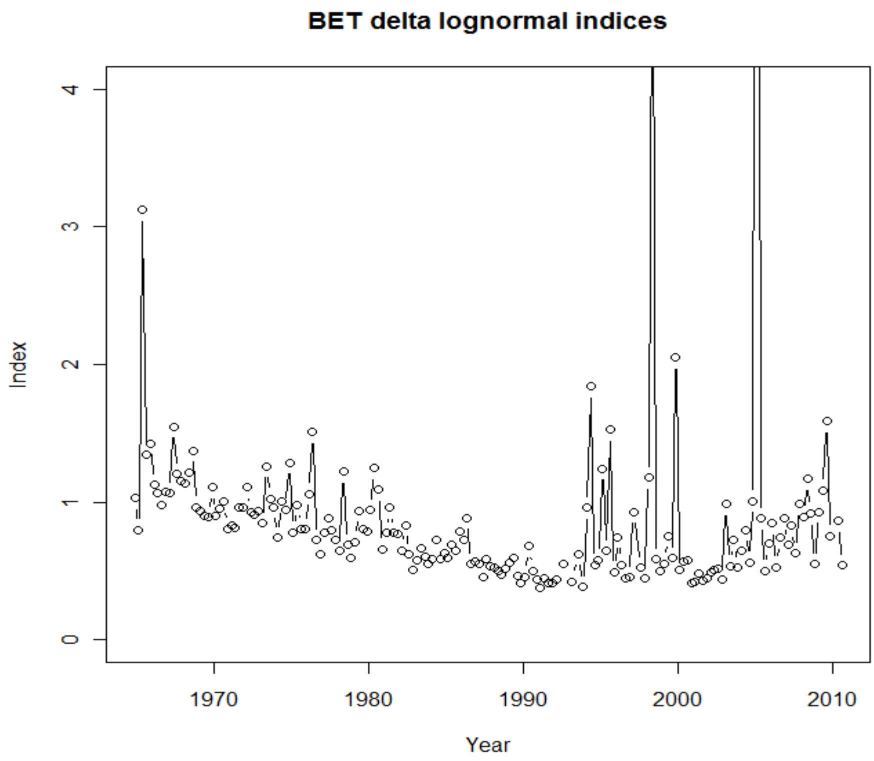

Fig. 12. Delta lognormal indices for bigeye tuna in region 6.

Table 2. ANOVA of the final standardization model for bigeye tuna.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Year*Quarter	179	317.30	1.77	85.00	0.0000
Grid	23	52.30	2.27	109.05	0.0000
Vessel ID	594	231.59	0.39	18.69	0.0000
Residuals	31837	663.91	0.02		

3.3. Regression tree analysis on albacore catch rate

Regression tree analysis on albacore catch rate (Fig. 13) shows that the most important classifying factor is latitude: it separates the data north of 15°S as one group and south of 15°S as another group. The latter group is further separated into additional two groups based number of hooks per day (2894 hooks).

The first level of classification criteria in Fig. 13 reflects the fact that many Taiwanese vessels targeting yellowfin/bigeye can fish down to 15°S, across the boundary of Region 4 and 6 (Fig. 1). Examination on the catch data in Region 6 (Fig. 14) shows high bigeye catch in recent years and these high catches were mostly made in the northern boundary of Region 6. A trial was therefore conducted to remove all the data from 10-15°S. Fig. 15 shows the regression tree, which is just the right-hand part of the first-level tree in Fig. 13. Three groups can also be separated from the tree; however it is difficult to interpret the features of each group. Delta-lognormal runs on this set of data however would not converge, and therefore further analyses on the CPUE series were abandoned.

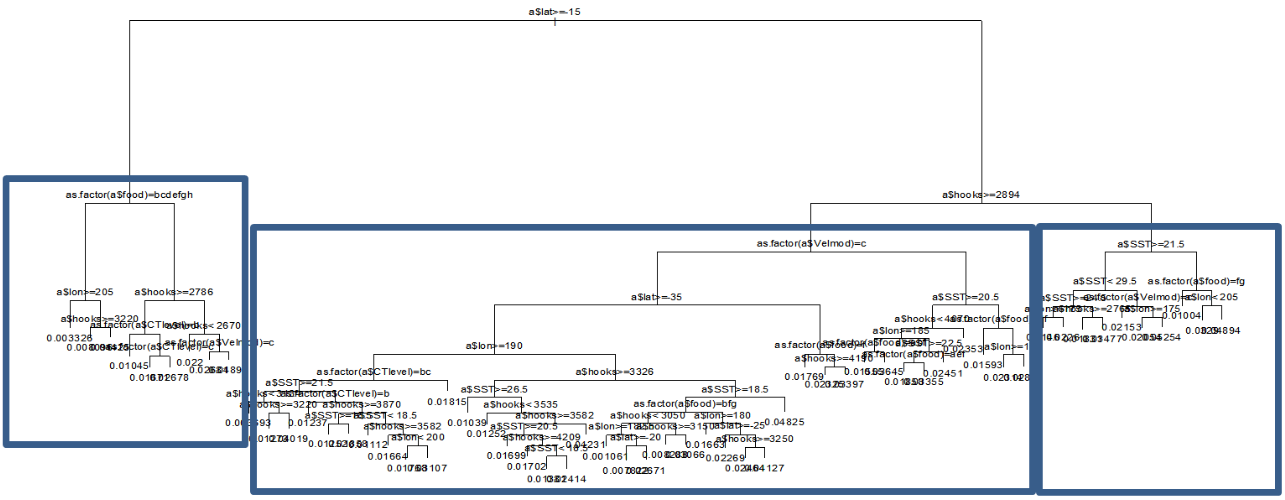

Fig. 13. Regression tree on albacore catch rate with whole data set.

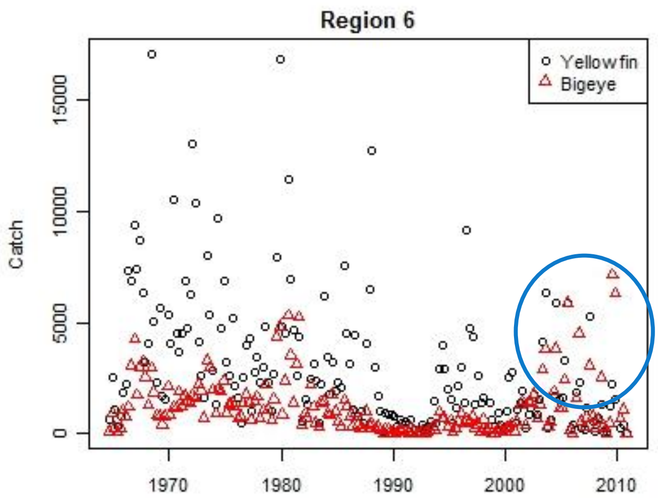

Fig. 14. Annual catch of bigeye and yellowfin tunas in Region 6 from recovered logbooks of Taiwanese distant-water longline vessels. The circle indicates the recent sharp increase in bigeye catch rate, probably due to increased targeting.

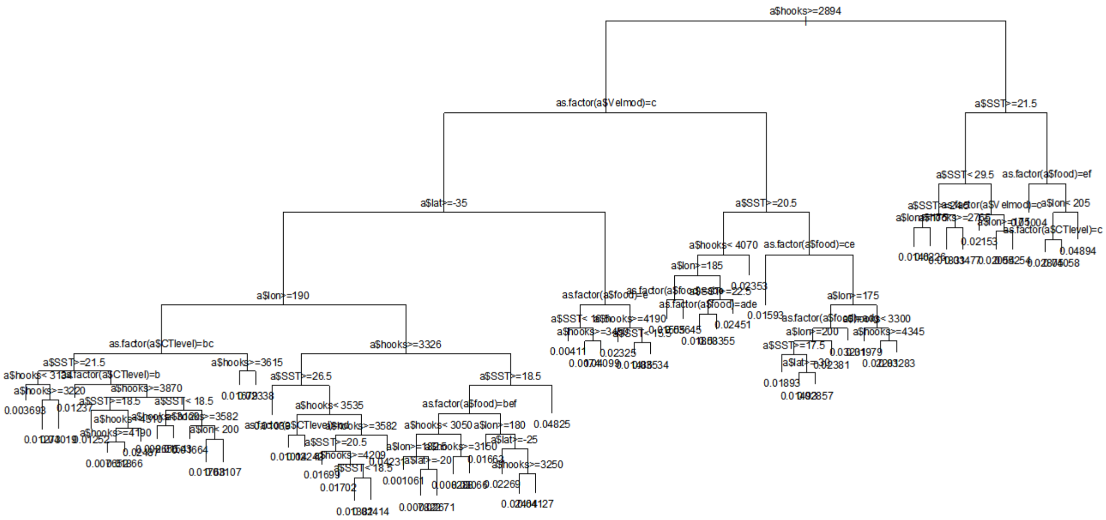

Fig. 15. Regression tree on albacore catch rate with data south of 15°S in Region 6.

Acknowledgement

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De'ath G. & Fabricius K. E. (2000) Classification and regression trees: a powerful yet simple technique for ecological data analysis. Ecology 81: 3178-3192.