Catch rate standardization of striped marlin in the Western and Central North Pacific Ocean by the Taiwanese tuna longline fisheries during 1995-2017

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Abstract

This report provides annual changes in standardized catch rate of striped marlin caught by Taiwanese distant-water tuna longline fishery (DWLL) (1995-2017) and small scale tuna longline fishery (STLL) (2008-2017) in the Western and Central North Pacific Ocean (WCNPO). Catch rates were standardized using delta lognormal generalized linear models (GLM) with year, month, latitude, and longitude as predictors. Step plots and coefficient–distribution–influence (CDI) plot are described to assist understanding the standardization effects of explanatory variables included in GLMs. Results showed that the standardized catch rate of DWLL has fluctuated overtime; recent peaks were observed in 2012-2013 and 2016-2017, respectively. The standardized catch rate of STLL has increased in 2012, then decreased in 2013 and stayed stable since then.

Introduction

We acknowledged that North Pacific striped marlin is experiencing overfishing and is overfished (Chang et al., 2015) and notes that the ISC BILLWG work plan for 2019 includes completing a benchmark North Pacific striped marlin assessment. In preparation for the next stock assessment of striped marlin in the Western and Central North Pacific Ocean (WCNPO; west of 150°W and north of the equator) in 2019, the objective of this paper is to provide the standardized CPUE index as necessary input data. Noted that the WCNPO striped marlin was mainly caught by the Taiwanese small scale tuna longliners (STLL) compared to distant-water tuna longliners (DWLL) (see definition in the *Fishery data*), weekly aggregated operational logbook dataset of the STLL and DWLL were used to derive standardized CPUE, respectively.

Materials and methods

Fishery data

Operational logbook data of the Taiwanese distant-water tuna longliners (DWLL) (1964-2017) and small scale tuna longliners (STLL) (2001-2017) in the WCNPO were obtained from the Oversea Fisheries Development Council. DWLL fishing vessels refer to those whose gross register ton (GRT) are larger than or equal to 100 GRT, which mostly operate in the high seas or in the EEZs of Pacific Island countries under access agreements, while STLL vessels generally refer to those vessels smaller than 100 GRT (mostly 50-70 GRT) (see ISC/18/PLENARY/05 for detail).

Statistical model

Standardizations were performed for weekly aggregated operational striped marlin catch and effort data of DWLL and STLL using GLM, respectively. This paper presents standardizations of DWLL and STLL dataset from 1995-2017 and 2008-2017, respectively, due to better quality and quantity of the dataset. Striped marlin caught primarily as bycatch in the both DWLL and STLL (**Fig. 1**). As these zeros can cause mathematical problems for fitting the models, we used the delta-lognormal (DLN) for the catch-rates standardization. The DLN analyzes separately the positive observations (positive process) and the probability that a null or positive observation occurs (zero process), and consists of two GLM which respectively use a lognormal and a binomial distribution. The logarithm of the CPUE is the response variable in the lognormal model and the identity is the link function. The proportion of positive captures is the response variable in the binomial model and the link function is the logit. The candidate factor variables followed the previous work from Sun et al. (2015), and included the years, months, latitudes and longitudes. The models were fitted by forward selection stepwise based on Akaike Information Criterion (AIC). At each step in the model selection procedure, the factor that resulted in the greatest reduction in AIC from the model in the previous step was added to the model.

Model diagnostics

Pearson and randomized quantile residuals (Dunn and Smyth, 1996) were plotted against fitted values and against each explanatory variable in lognormal and a binomial model, respectively. Histograms of residuals were used to assess normality for all models, in addition the quantile-quantile normal probability plots (Q-Q plot) for both of the lognormal and binomial models.

Year effect and its precision

Relative indices for the delta model formulation were calculated as the product of the year effect least square means (lsmeans package; Lenth, 2016) from the binomial and the lognormal model components. The standardized CPUE index and its variance were calculated as the mean and variance, respectively, of the predicted values on the scale of the response in each year using the “ref.grid” function of package lsmeans in R. The variance of the delta-lognormal distribution was calculated as the Taylor series expansion of the variance of the product of two independent random variables (see Brodziak and Walsh, 2013):

$$Var(\Delta C) = Var(\Delta)Var(C) + Var(\Delta)E(C)^2 + Var(C)E(\Delta)^2$$

where $E(\Delta)$, $Var(\Delta)$, $E(C)$, $Var(C)$ are the mean and variance of the standardized annual encounter rate and CPUE, respectively.

Bias-correction was applied when back-transforming the positive process of the DLN model from ln(CPUE) to CPUE. All statistical analyses for this paper were carried out with the R Project for Statistical Computing version 3.1.0 (R Core Team, 2014).

Influence plots and metrics for the lognormal model

For better understanding CPUE standardization, step plot and annual influence plot of the influ package (Bentley et al., 2012) were conducted for the lognormal model. In addition, the coefficient–distribution–influence (CDI) plot was used to examine the patterns of annual influence. Due to the limitation of the influ package, the influence analysis was not conducted for the binomial model.

Results and discussion

The spatial distributions of the nominal CPUE of striped marlin by the DWLL and STLL in the Western and Central North Pacific Ocean were shown in **Figs. 2 and 3**. Deviance tables for CPUE standardization models of the DWLL and STLL were shown in **Tables 1 and 2**. The Q-Q plots for all the models of the DWLL and STLL based on the lognormal distributions appear normal in the GLM analysis (**Figs. 4 and 5**), which confirms the assumption of error distribution is appropriate for the CPUE standardization. Partial residual plots by factor confirmed that there is no non-random distribution of residuals. Furthermore, the Q-Q plots of the randomized quantile residuals of the binomial model also showed normality in the distribution of the residuals (**Figs. 6 and 7**). The change in the DWLL CPUE index decrease slightly in 1997 in the step plot after “latitude” is introduced into the model (**Fig. 8**).

Figures 9-11 are the CDI plots for month, latitude, and longitude, the variable of latitude has shown the greatest variation in annual influence. The time-series trends of the standardized striped marlin CPUE by the DWLL was shown in **Fig. 12**. The standardized CPUE of DWLL has fluctuated overtime. Recent peaks of the index were observed in 2012-2013 and 2016-2017, respectively.

Step plot for the positive process CPUE standardization model of striped marlin by the STLL was shown in **Fig. 13**. There is less change in the STLL CPUE index in the step plot. **Figures 14-16** are the CDI plots for month, latitude, and longitude; there is little influence on annual CPUE indices. The time-series trends of the standardized striped marlin CPUE by the STLL was shown in **Fig. 17**. The standardized CPUE of STLL has increased in 2012, then decreased in 2013 and stayed stable since then.

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Table 1. Deviance tables for the positive process CPUE standardization model of striped marlin for the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean during 1995-2017.

Predictor	**Df**	**Deviance**	**Resid. Df**	**Resid. Dev**	**Pr (> Chi)**
Positive process					
NULL			6178	4661.4	
Year	22	313.65	6156	4347.7	< 0.01 ***
Month	11	85.54	6145	4262.2	< 0.01 ***
Lat	8	169.30	6137	4092.9	< 0.01 ***
Lon	16	52.88	6121	4040.0	< 0.01 ***
Zero process					
NULL			17166	22433	
Year	22	674.40	17144	21759	< 0.01 ***
Month	11	144.75	17133	21614	< 0.01 ***
Lat	8	865.92	17125	20748	< 0.01 ***
Lon	17	212.09	17108	20536	< 0.01 ***

Table 2. Deviance tables for the positive process CPUE standardization model of striped marlin for the Taiwanese small scale tuna longliners (STLL) in the Western and Central North Pacific Ocean during 2008-2017.

Predictor	**Df**	**Deviance**	**Resid. Df**	**Resid. Dev**	**Pr (> Chi)**
Positive process					
NULL			15130	12291	
Year	9	265.03	15121	12026	< 0.01 ***
Month	11	691.89	15110	11334	< 0.01 ***
Lat	8	231.85	15102	11102	< 0.01 ***
Lon	20	129.40	15082	10973	< 0.01 ***
Zero process					
NULL			109814	88055	
Year	9	1119.6	109805	86935	< 0.01 ***
Month	11	1851.3	109794	85084	< 0.01 ***
Lat	9	4287.6	109785	80797	< 0.01 ***
Lon	21	2002.9	109764	78794	< 0.01 ***

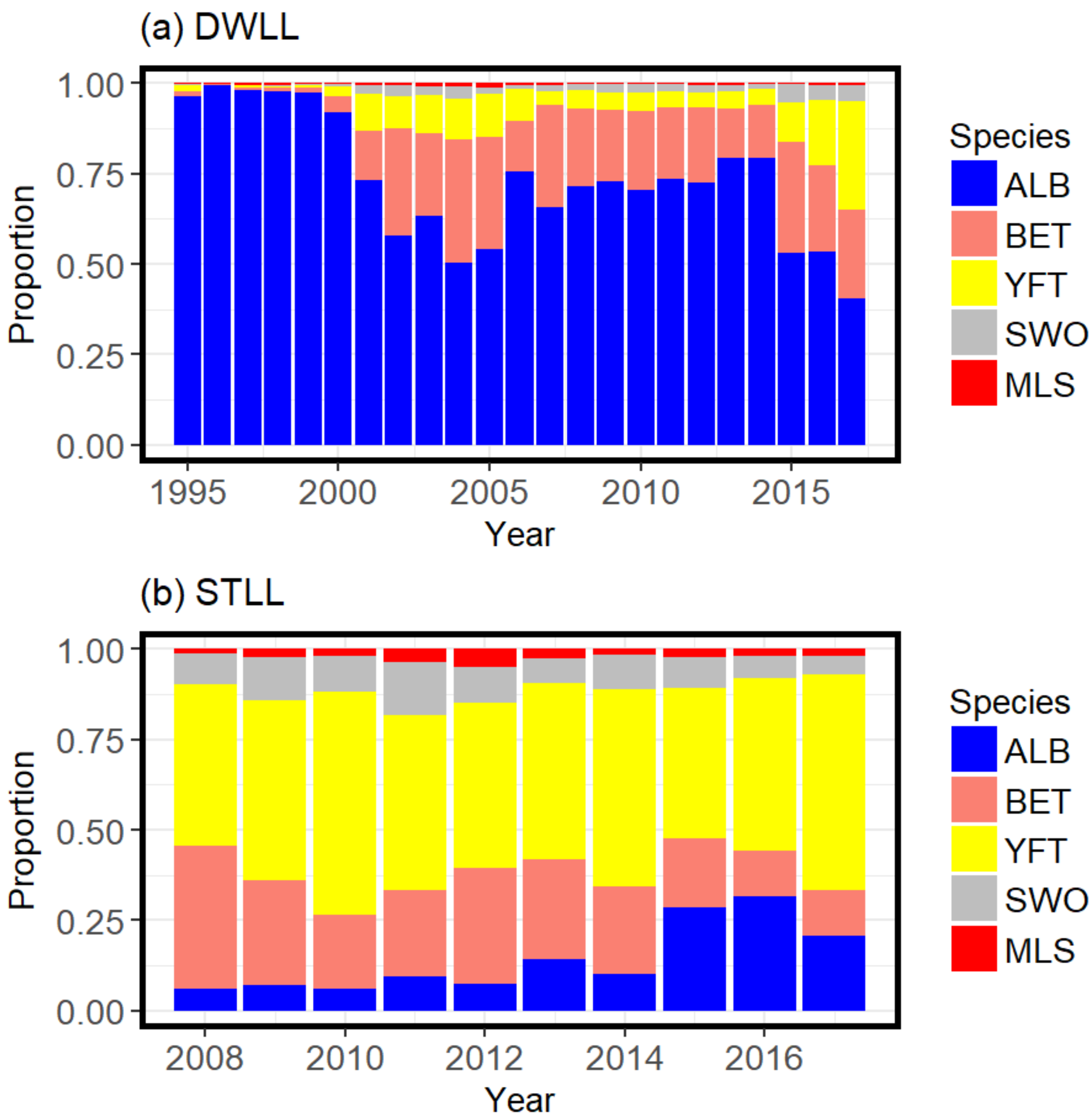

Figure 1. Annual catch proportions of albacore tuna, bigeye tuna, yellowfin tuna, swordfish, and striped marlin by the Taiwanese distant-water (a) and small scale (b) tuna longliners in the Western and Central North Pacific Ocean during 1995-2017 and 2008-2017, respectively.

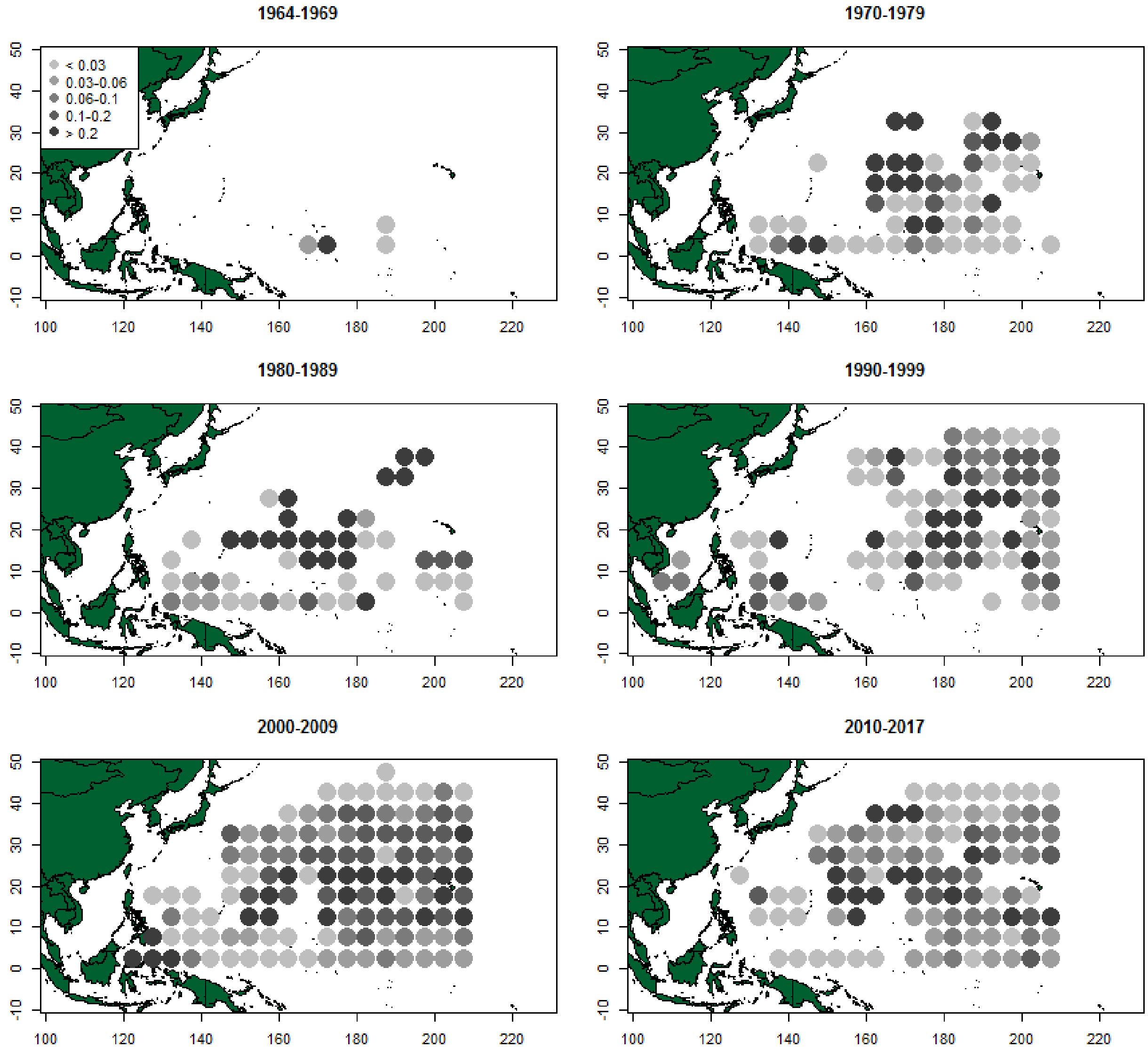

Figure 2. Distributions of nominal CPUE (number of fish caught per 1000 hooks) of striped marlin by the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean.

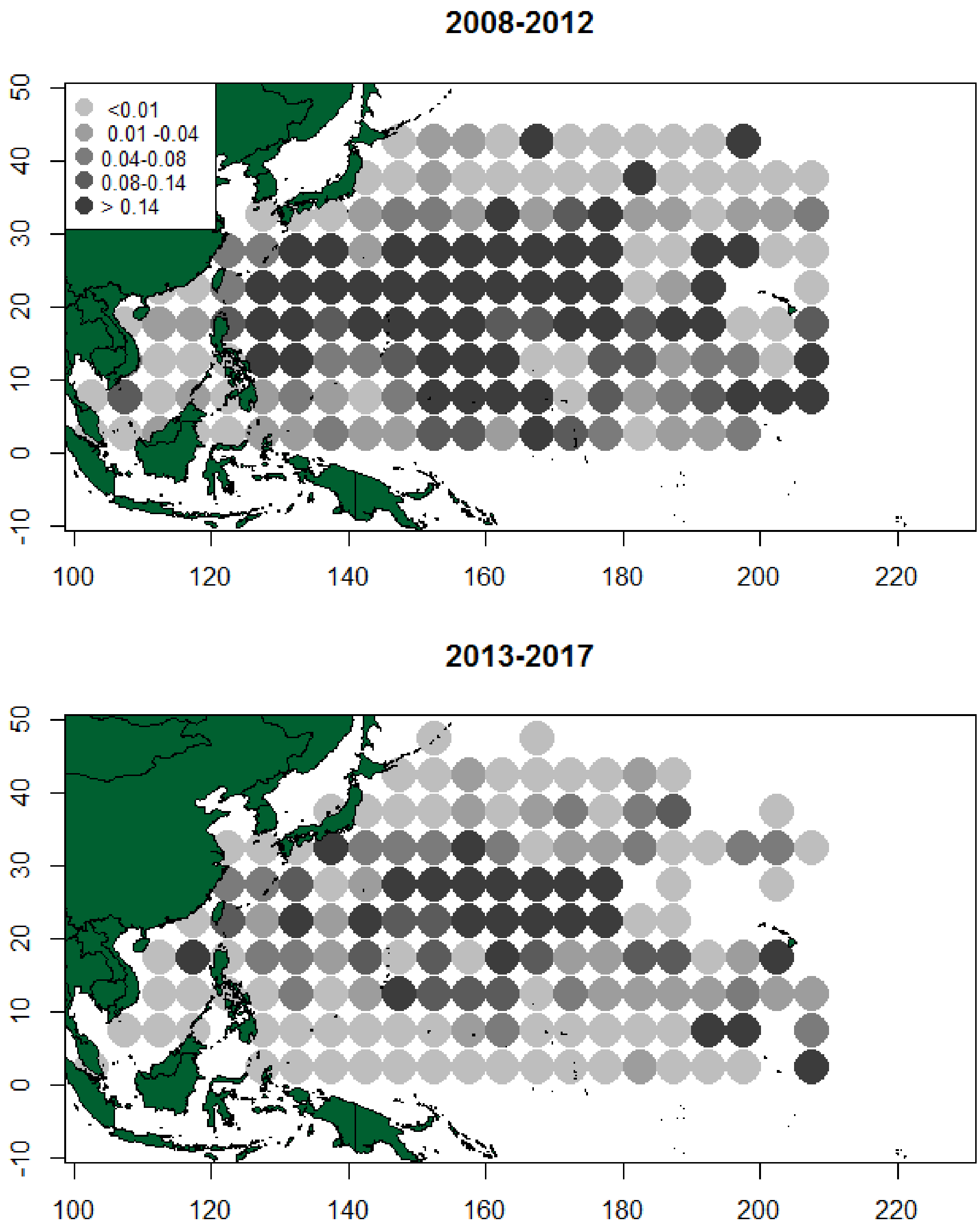

Figure 3. Distributions of nominal CPUE (numbers of fish caught per 1000 hooks) of striped marlin by the Taiwanese small scale tuna longliners (STLL) in the Western and Central North Pacific Ocean during 2008-2012 (a) and 2013-2017 (b).

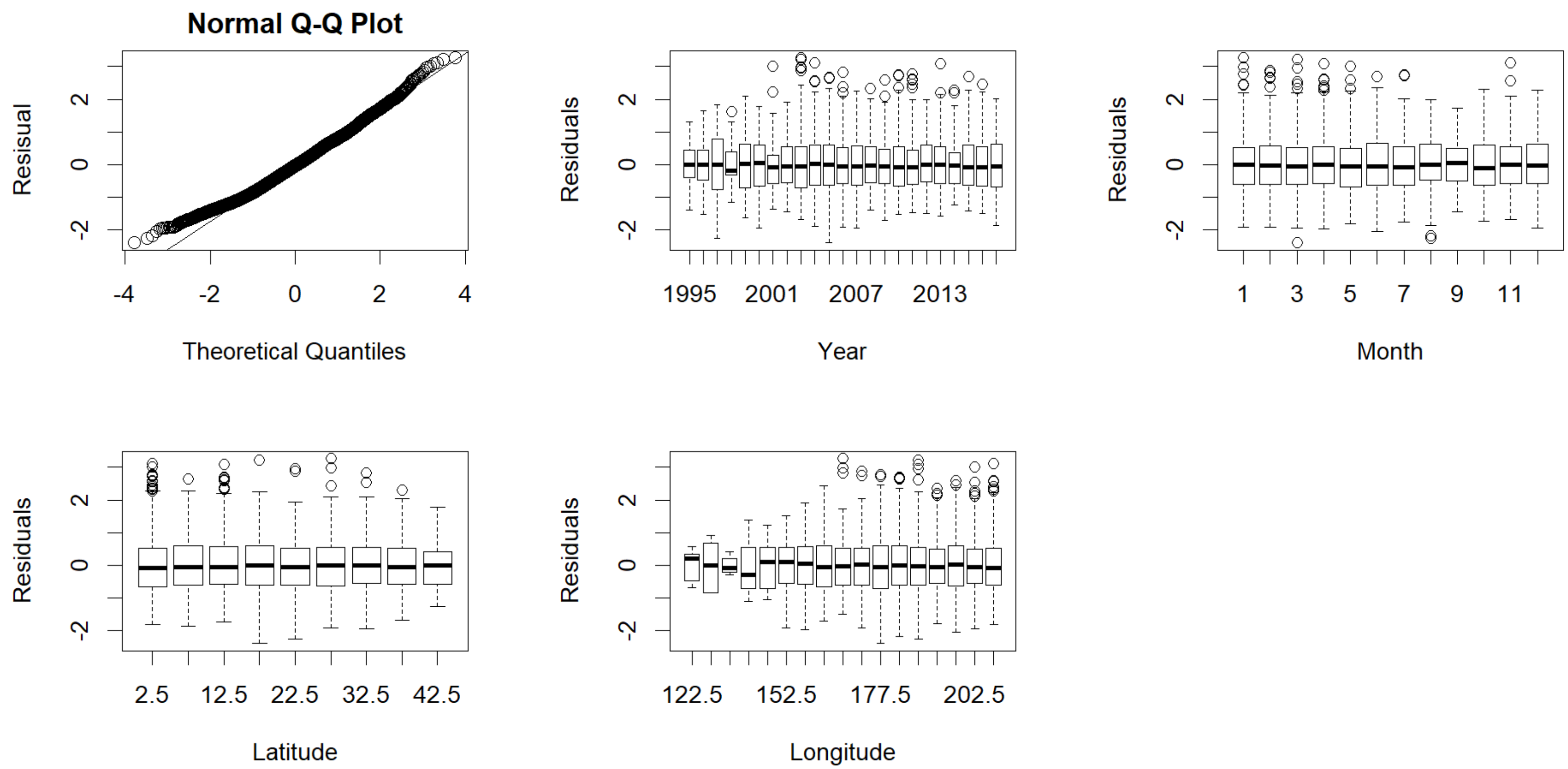

Figure 4. Residual diagnostics for the positive process CPUE standardization model of striped marlin for the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean.

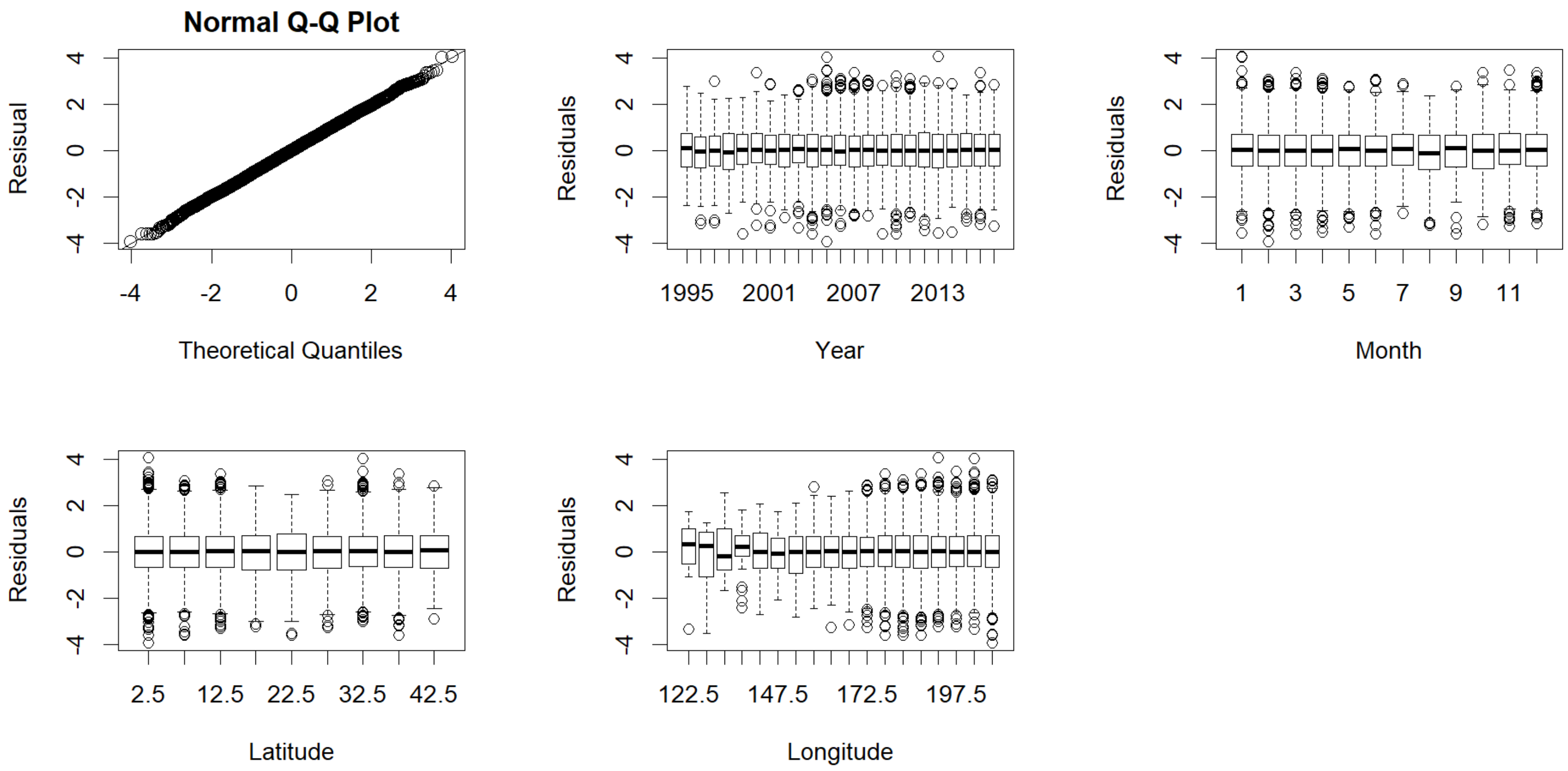

Figure 5. Residual diagnostics for the binomial process CPUE standardization model of striped marlin for the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean

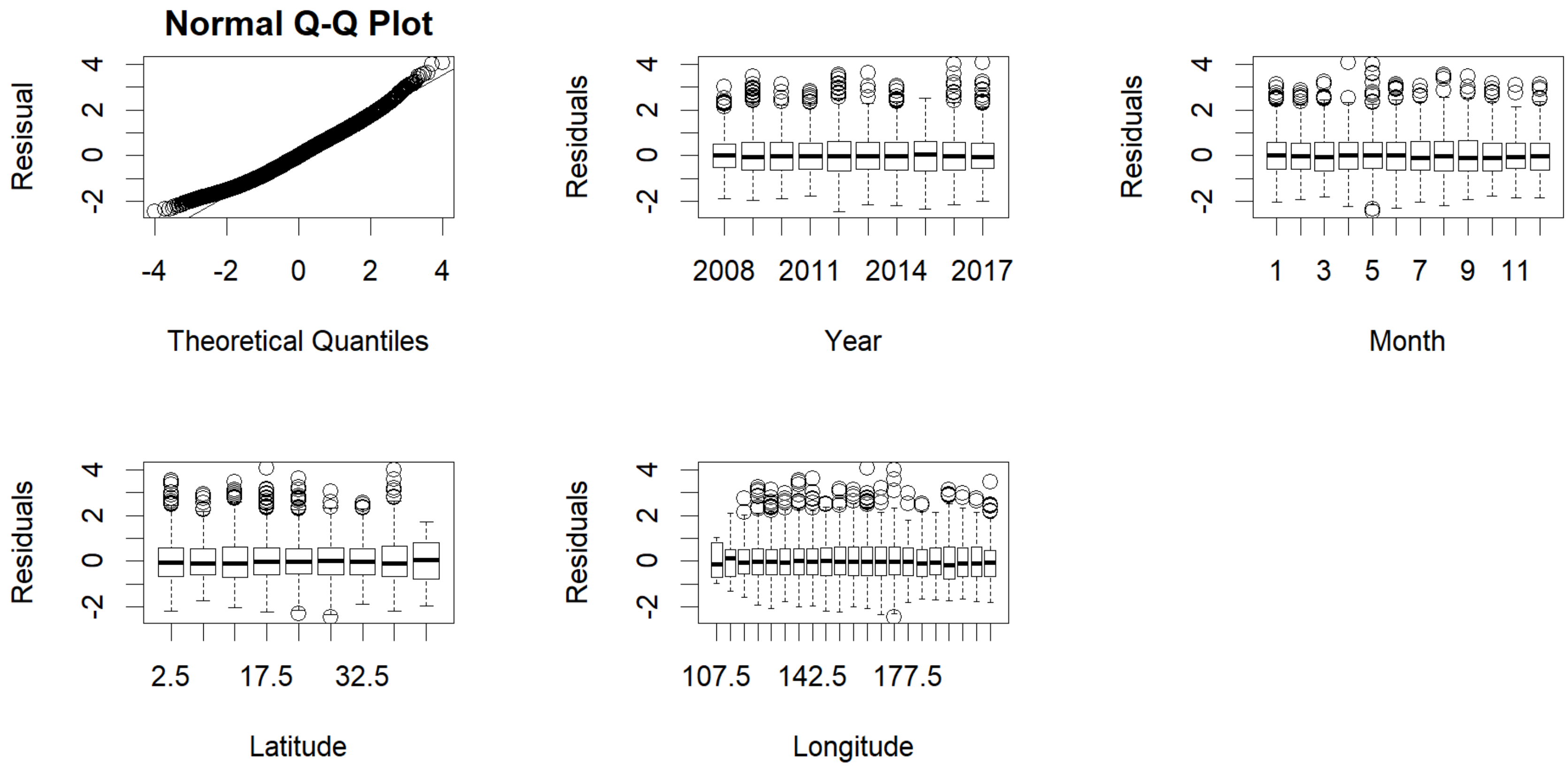

Figure 6. Residual diagnostics for the positive process CPUE standardization model of striped marlin for the Taiwanese small scale tuna longliners (STLL) in the Western and Central North Pacific Ocean.

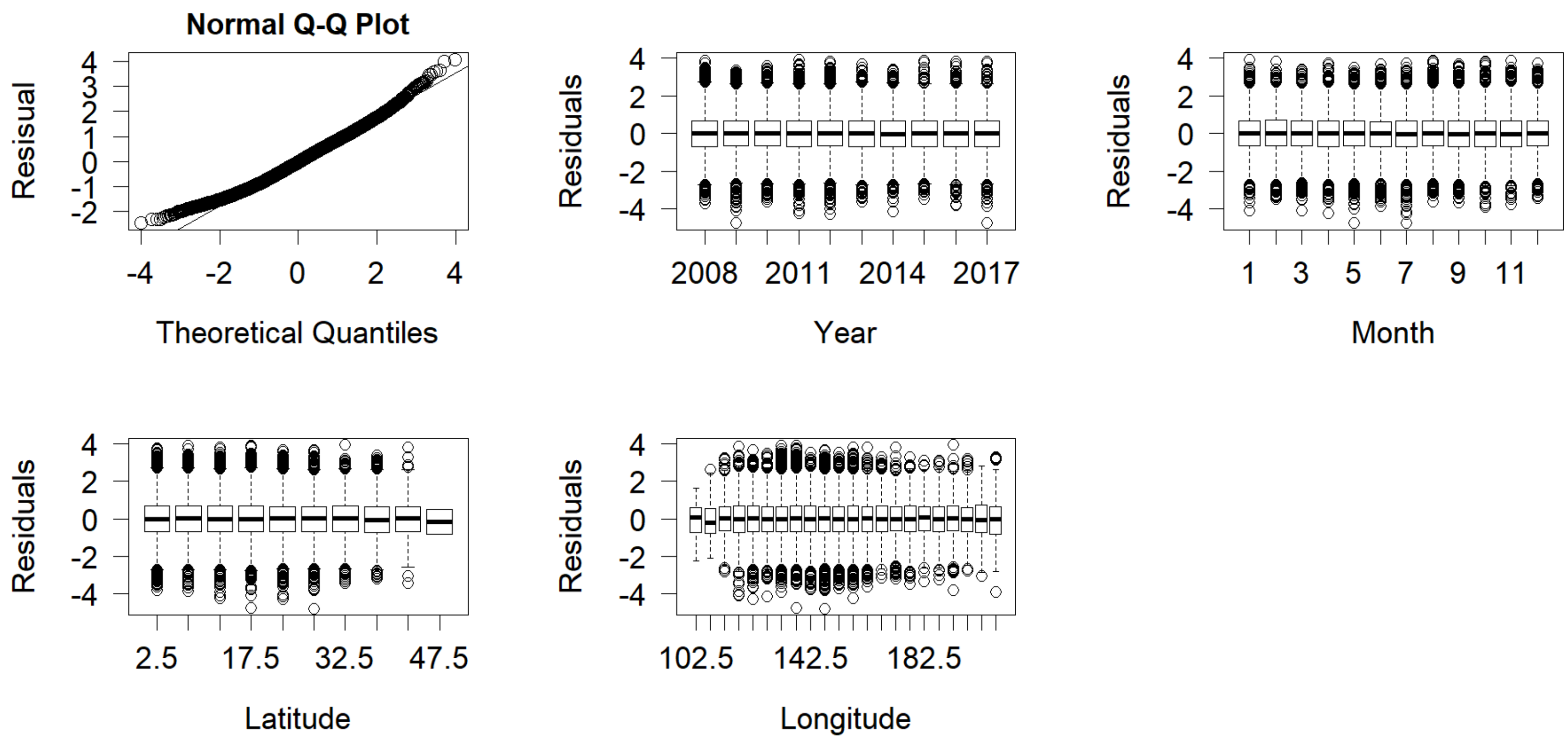

Figure 7. Residual diagnostics for the binomial process CPUE standardization model of striped marlin for the small scale longliners (STLL) in the Western and Central North Pacific Ocean.

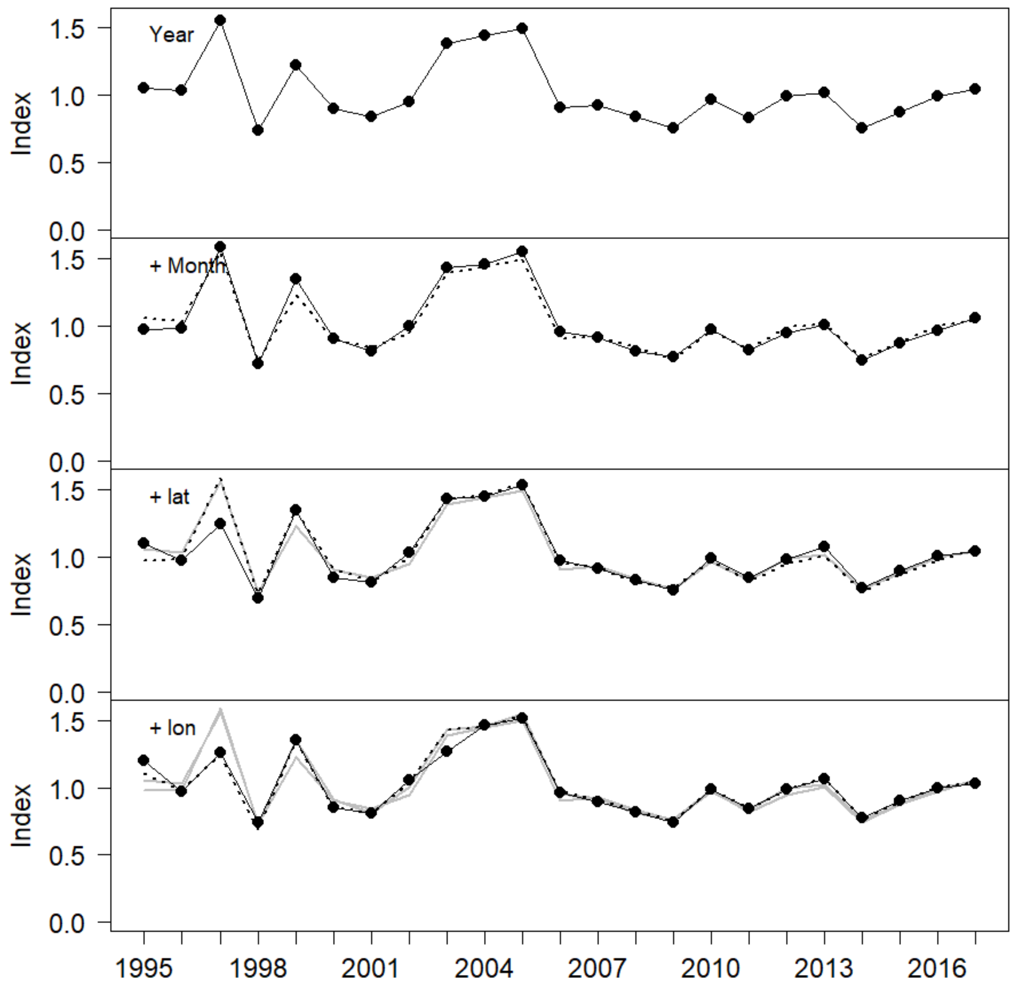

Figure 8. Step plot for the positive process CPUE standardization model of striped marlin for the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean.

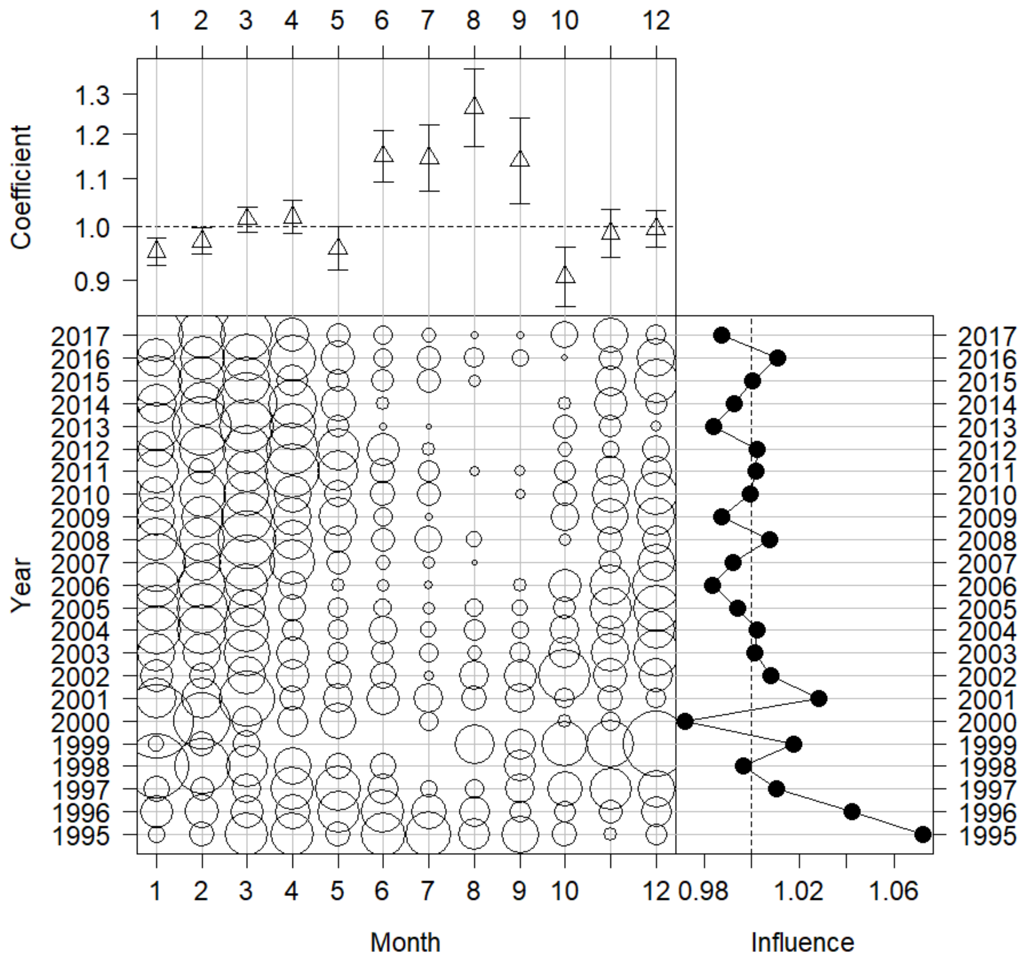

Figure 9. Month coefficient-distribution-influence (CDI) plot for the positive process CPUE standardization model of striped marlin for the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean.

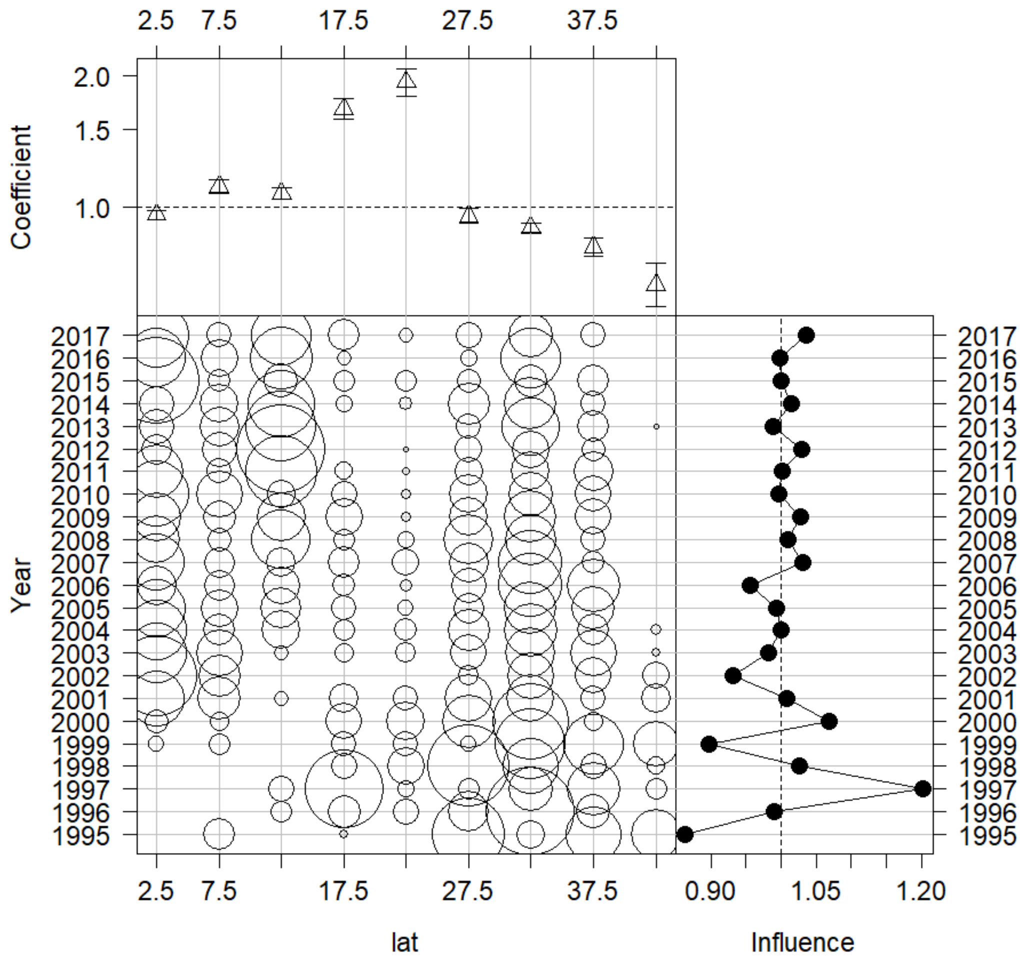

Figure 10. Latitude coefficient-distribution-influence (CDI) plot for the positive process CPUE standardization model of striped marlin for the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean.

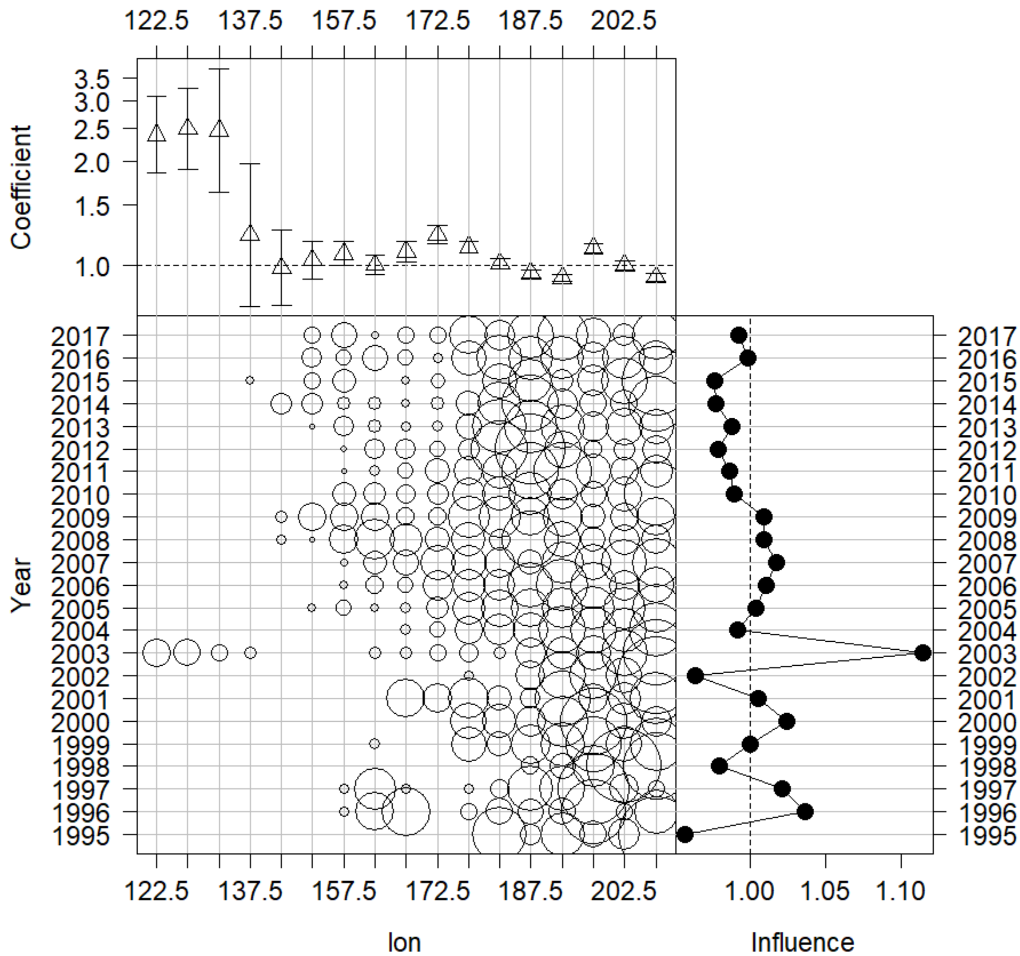

Figure 11. Longitude coefficient-distribution-influence (CDI) plot for the positive process CPUE standardization model of striped marlin for the Taiwanese distant-water tuna longliners (DWLL) in the Western and Central North Pacific Ocean.

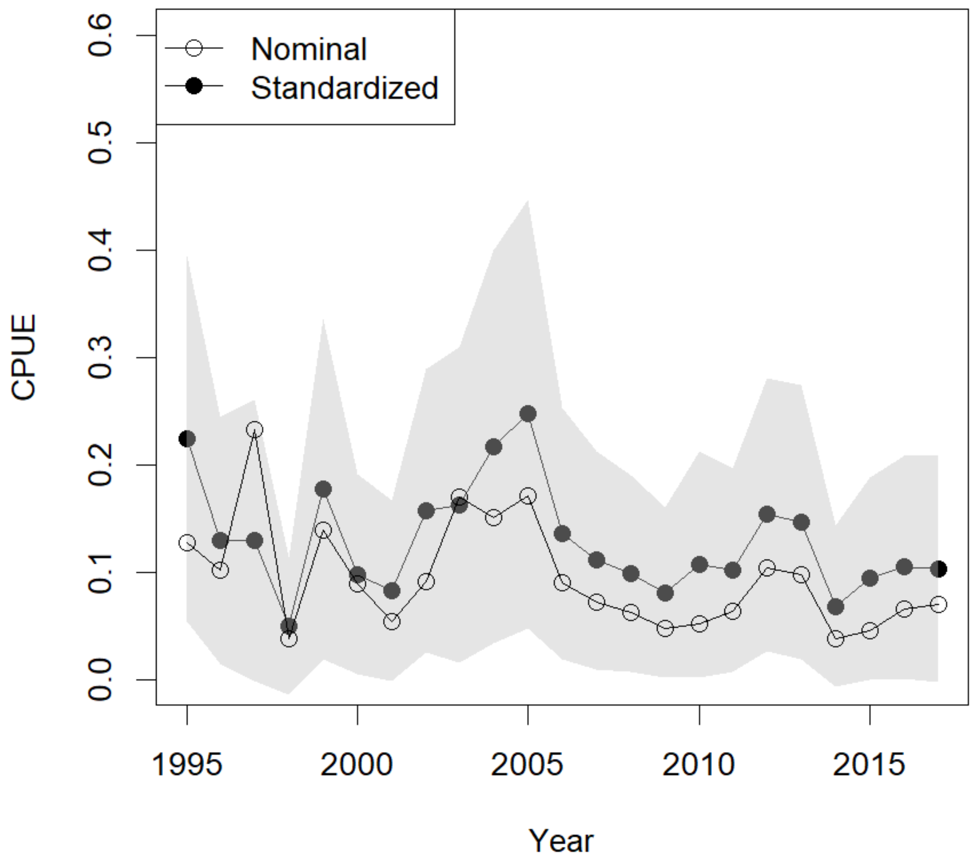

Figure 12. Nominal (total numbers of fish caught/total number of hooks) and standardized CPUE indices (product of the year effects of the presence–absence component and positive catch component.) for the striped marlin in the Western and Central North Pacific Ocean by the Taiwanese distant-water tuna longliners (DWLL) during 1995-2017. Shaded area indicates ± 1 s.e..

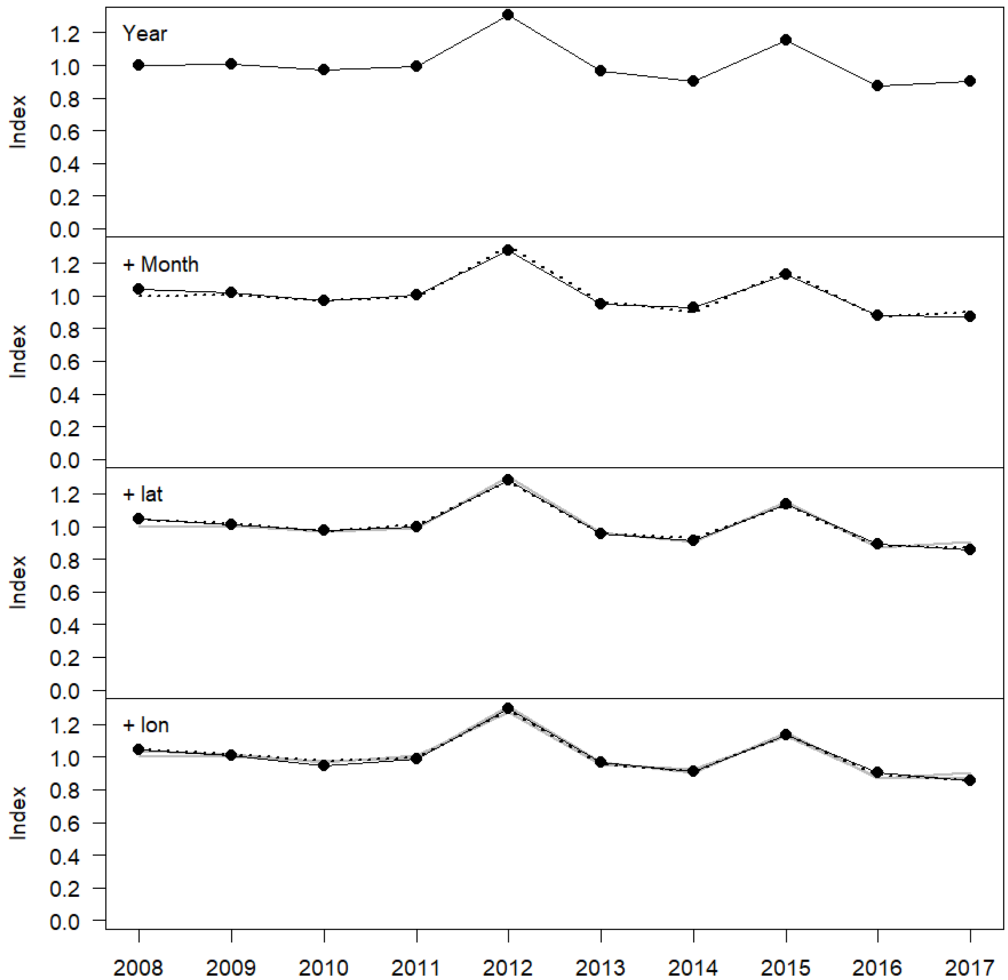

Figure 13. Step plot for the positive process CPUE standardization model of striped marlin for the Taiwanese small scale (STLL) in the Western and Central North Pacific Ocean.

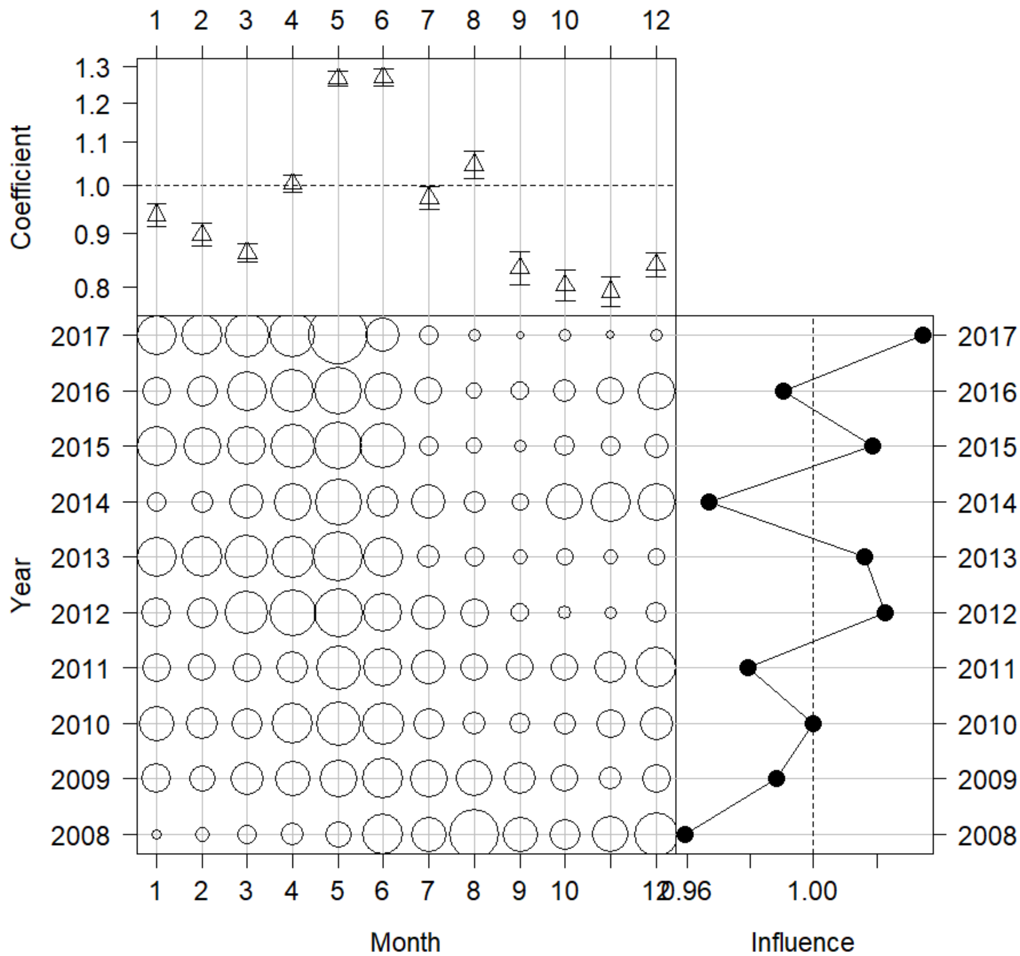

Figure 14. Month coefficient-distribution-influence (CDI) plot for the positive process CPUE standardization model of striped marlin for the Taiwanese small scale tuna longliners (STLL) in the Western and Central North Pacific Ocean.

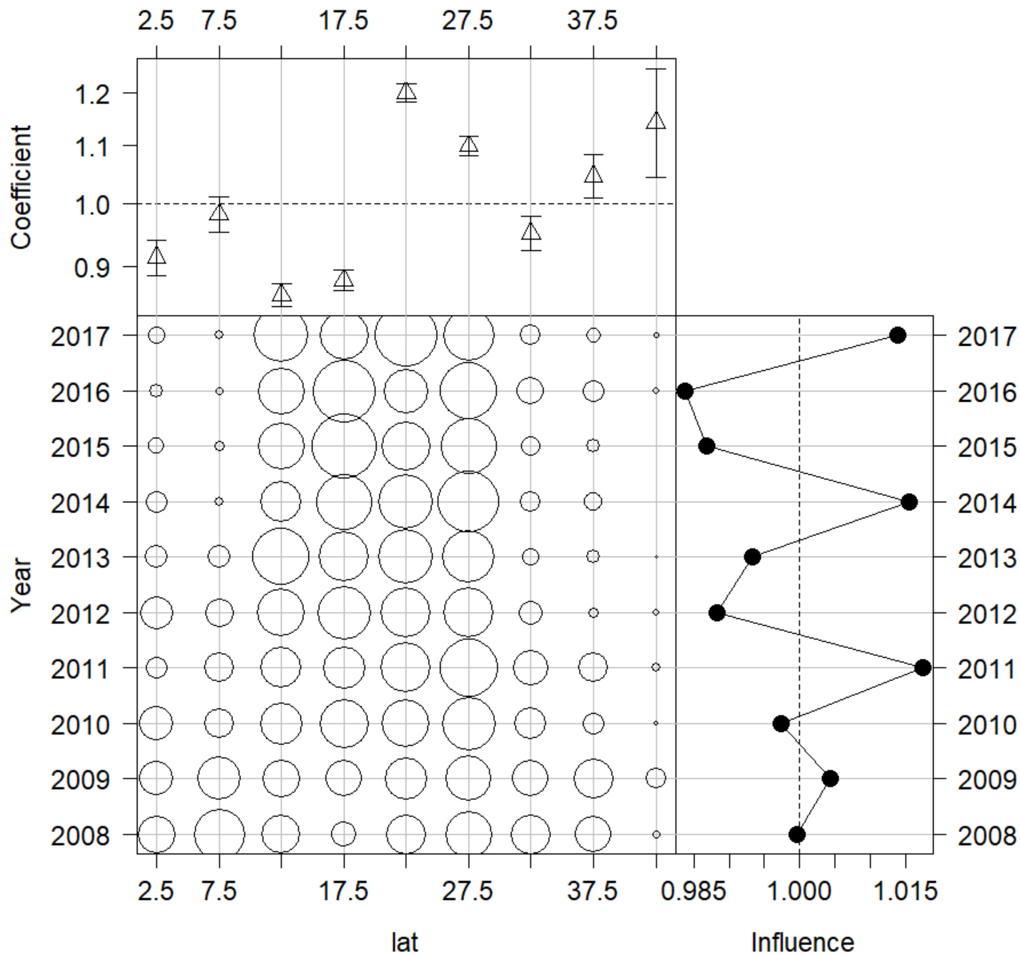

Figure 15. Latitude coefficient-distribution-influence (CDI) plot for the positive process CPUE standardization model of striped marlin for the Taiwanese small scale tuna longliners (STLL) in the Western and Central North Pacific Ocean.

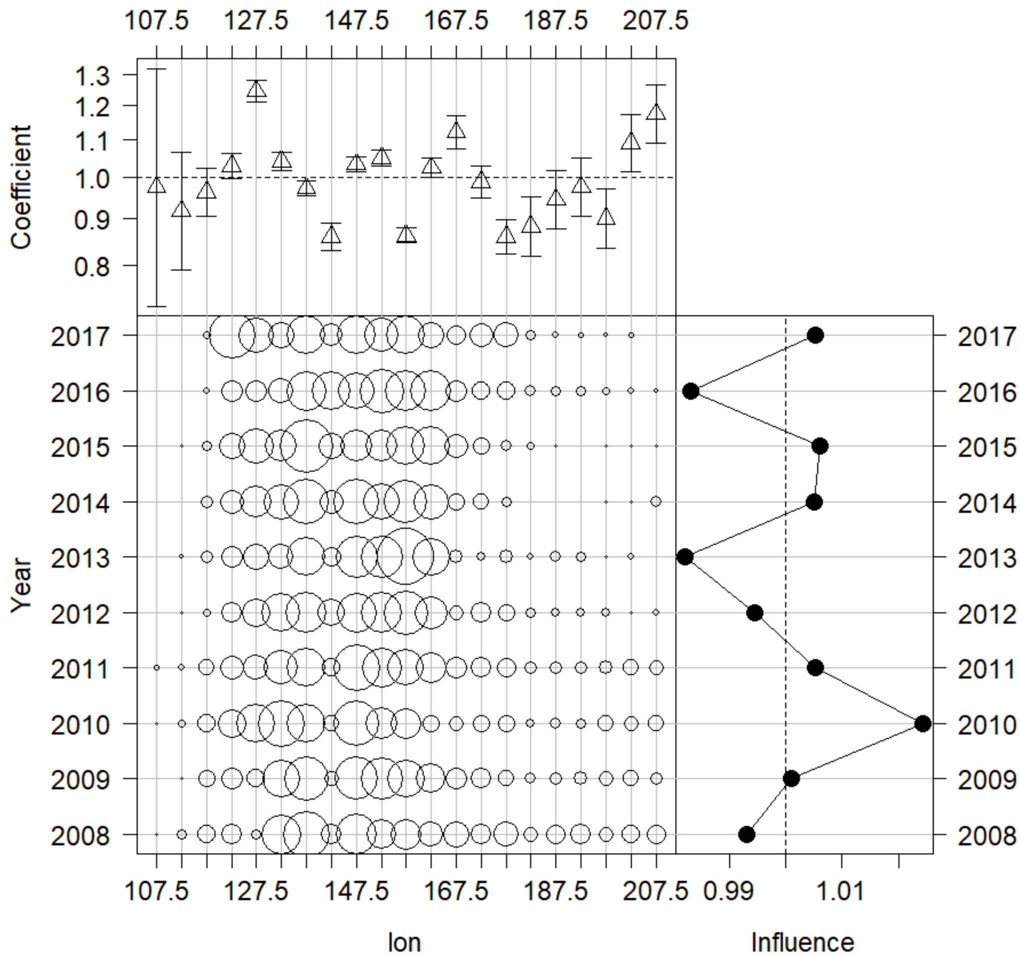

Figure 16. Longitude coefficient-distribution-influence (CDI) plot for the positive process CPUE standardization model of striped marlin for the Taiwanese small scale tuna longliners (STLL) in the Western and Central North Pacific Ocean.

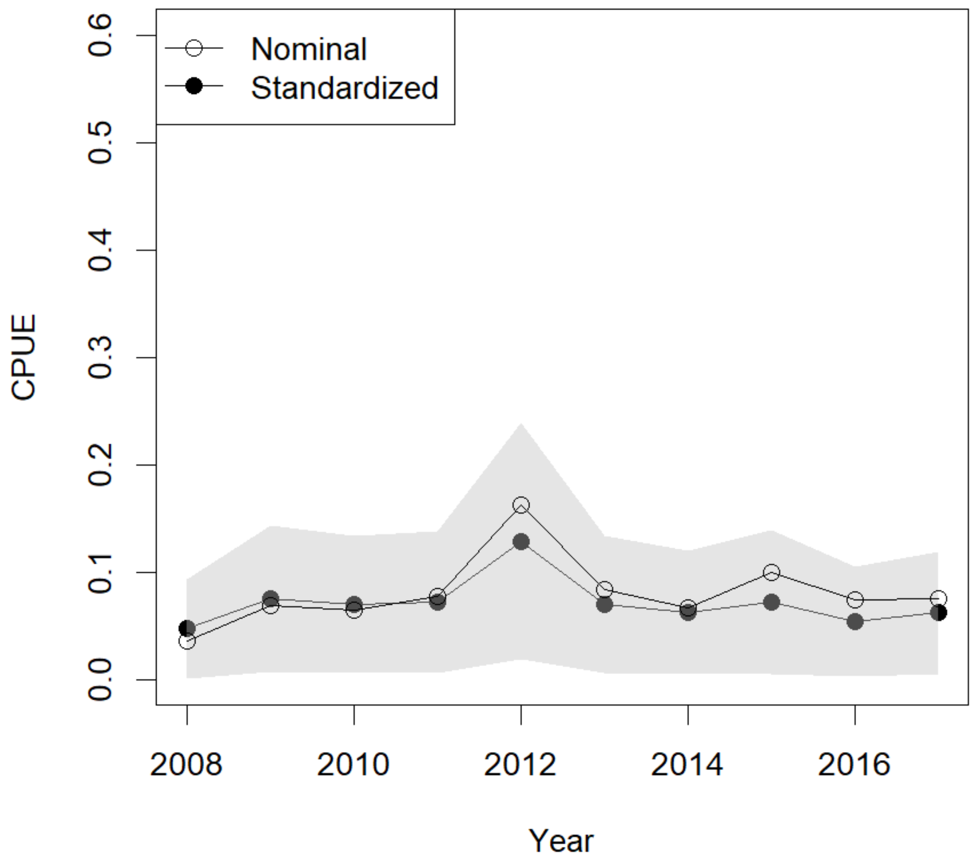

Figure 17. Nominal (total numbers of fish caught/total number of hooks) and standardized CPUE indices (product of the year effects of the presence–absence component and positive catch component.) for the striped marlin in the Western and Central North Pacific Ocean by the Taiwanese small scale tuna longliners (STLL) during 1995-2017. Shaded area indicates ± 1 s.e..