CPUE standardization for southern bluefin tuna caught by Taiwanese longline fishery

Sheng-Ping Wang[1], Shu-Ting Chang[2], Shiu-Ling Lin[3], I-Lu Lai[3],

[1] National Taiwan Ocean University, Taiwan
[2] Overseas Fisheries Development Council, Taiwan
[3] Fisheries Agency, Council of Agriculture, Executive Yuan, Taiwan

ABSTRACT

This study attempts to conduct the CPUE standardization for southern bluefin tuna caught by Taiwanese longline fishery using a general linear model. Standardized CPUEs generally reveal quite different trends for different area. Generally, standardized CPUEs substantially decreased for all areas in recent years. It is apparent that the CCSBT statistical areas may not be appropriate for Taiwanese SBT fishery. In addition, the CPUEs of other tunas may not be explanatory effects when conducting CPUE standardization for Taiwanese SBT fishery.

1. INTRODUCTION

Southern bluefin tuna (SBT) (*Thunnus maccoyii*) was by-catch of Taiwanese tuna longline fishery targeting albacore in the past, but after the fishing vessels equipped with deep-frozen freezers, some fishing vessels operating in the Indian Ocean started targeting SBT seasonally since 1990s. Since Taiwanese SBT statistics system was reformed in 2002, the reporting rate of SBT catch has substantially improved since then (Anon, 2014). This study attempted to conduct the CPUE standardization for SBT caught by Taiwanese longline fishery for year of 2002-2013.

2. MATERIALS AND METHODS

2.1. Catch and Effort data

In this study, monthly catch and effort data with 5x5 degree fishing location grids of Taiwanese active longline vessels authorized to seasonally target SBT operating in the Indian Ocean in the period of 2002-2013 were provided by Overseas Fisheries Development Council of Taiwan (OFDC).

2.2. Definition of fishing areas

Based on the catch and CPUE distributions, two fishing ground (Area1, in the area of 20°S-40°S and east of 50°E; Area 2, in the area of 20°S-45°S and 20°E-50°E) should be appropriate to Taiwanese SBT longline fishery (Anon, 2013). However, the ESC17 indicated that “current area stratification may be appropriate for the Taiwanese data, but that if the spatial strata were the CCSBT statistical areas then comparisons could be made with the other longline CPUE indices (CCSBT, 2012).” Therefore, the CCSBT statistical areas were also adopted for the analysis of Taiwanese CPUE standardization (Fig. 1).

2.3. CPUE standardization

The general linear model (GLM) is applied to standardize the CPUE of SBT caught by Taiwanese longline fishery. The effects included in the models were year, month, fishing area, longitude, latitude, CPUEs of albacore, bigeye and yellowfin tuna, and their interactions. The GLM is conducted as below:

$$\ln(CPUE + c) = \mu + Y + M + A + Lon + Lat + BET + ALB + YFT + \text{interactions} + \varepsilon$$

where
$CPUE$ is the nominal CPUE of SBT (catch in number/1,000 hooks),
c is the constant value (i.e. 10% of the average nominal CPUE),
μ is the intercept,
Y is the year effect,
M is the month effect,

A	is the fishing area effect,
Lon	is the longitude effect,
Lat	is the latitude effect,
ALB	is the albacore CPUE effect,
BET	is the bigeye tuna CPUE effect,
YFT	is the yellowfin tuna CPUE effect,
ε	is the error term, $\varepsilon \sim N(0, \sigma^2)$.

The effects of year, month and area were treated as categorical variables, while the effect of longitude, latitude and CPUEs of albacore and bigeye tuna are treated as continuous variables. Regarding the effect of interaction related to year effect, an interaction between year and area was only included in this study for the further estimates of the area-specific CPUE standardization because interactions with the year effect would lead to problems for the year effect as an index of abundance (Hinton and Maunder, 2004; Maunder and Punt, 2004). The area-specific standardized CPUE trends were estimated based on the exponentiations of the adjust means of the interaction between year and area effects, i.e. $Y \times A$ (Butterworth, 1996; Maunder and Punt, 2004).

3. RESULTS AND DISCUSSIONS

3.1. Summary of GLM statistics

Firstly, we performed the GLM without the effects of interactions to explore the significances of main effects. The results indicated that the effects of CPUEs of albacore and yellowfin tuna were not statistically significant (Table 1). Therefore, the effects of CPUEs of albacore and yellowfin tuna were removed from the GLM.

Secondly, we conducted GLM by incorporating the effects of interactions. Because SBT catch did not occur in every months and areas, too many missing values were occurred when incorporating the interaction between month and area. In addition, some interactions were not statistically significant. Therefore, a final GLM was conducted as

$$\ln(CPUE + c) = \mu + Y + M + A + Lon + Lat + BET$$
$$+ Y \times A + M \times Lon + M \times Lat + A \times BET + \varepsilon$$

The ANVOA table for the final GLM is shown in Table 2 and all of main effects and interactions were statistically significant. However, the explanatory ability of the area effect was quite low. The effects of longitude and latitude were much more explanatory than other main effects and interactions.

The distribution of standardized residuals obviously concentrates around 0 and the Quantile-Quantile Plot also indicates that the distribution of residuals fits to the assumption of normal distribution (Fig. 2).

3.2. Trend of standardized CPUE

Fig. 3 shows the area-specific standardized CPUE estimated based on incorporating the definition of CCSBT statistical areas (Fig. 2). The trends of standardized CPUE in Areas 2 and 14 are similar and both of them increase before 2007 and reveal decreasing pattern thereafter, except for the peak observed for area 2 in 2012. The standardized CPUE is Area 9 is relatively stable than those in other areas. The standardized CPUE in Area 8 reveals increasing trend before 2010 but decreased thereafter. In recent years, however, standardized CPUEs substantially decreased for all areas. Fig. 4 shows the comparisons between area-specific standardized and nominal CPUE. In general, the trends of standardized CPUE were relatively smooth than those of nominal CPUE.

Based on the results of this study, the area effect based on CCSBT statistical area has a low explanatory ability for GLM. Wang et al. (2013) also indicated that the main SBT fishing grounds were separated into several parts by CCSBT statistical areas and thus the definition of CCSBT statistical areas may not be appropriate to be adopted for the CPUE analysis of SBT caught by Taiwanese SBT fishery. In addition, the explanatory ability of the effects of CPUE of other tunas was not statistically significant. This may reflect the results of Wang et al. (2014), which indicated that there was no particular operation pattern for targeting other tunas and SBT CPUE was not strongly affected by targeting issue.

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Table 1. ANOVA table for GLM without effect of interactions.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	30	1964.18	65.47	52.76	<.0001
Error	2190	2717.45	1.24		
Corrected Total	2220	4681.63			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.42	-80.92	1.11	-1.38

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	11	63.63	5.78	4.66	<.0001
M	11	815.88	74.17	59.77	<.0001
A	3	130.38	43.46	35.02	<.0001
Lon	1	136.29	136.29	109.83	<.0001
Lat	1	200.41	200.41	161.51	<.0001
ALB	1	0.96	0.96	0.78	0.3781
BET	1	5.75	5.75	4.63	0.0315
YFT	1	2.07	2.07	1.67	0.1962

Table 2. ANOVA table for GLM incorporated the effects of interactions.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	86	2413.08	28.06	26.39	<.0001
Error	2134	2268.54	1.06		
Corrected Total	2220	4681.63			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.52	-74.90	1.03	-1.38

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	11	41.34	3.76	3.54	<.0001
M	11	91.80	8.35	7.85	<.0001
A	3	8.49	2.83	2.66	0.0465
Lon	1	161.32	161.32	151.75	<.0001
Lat	1	122.21	122.21	114.96	<.0001
BET	1	6.07	6.07	5.71	0.017
Y*A	33	94.16	2.85	2.68	<.0001
Lon*M	11	277.67	25.24	23.75	<.0001
Lat*M	11	97.89	8.90	8.37	<.0001
BET*A	3	12.14	4.05	3.81	0.0098

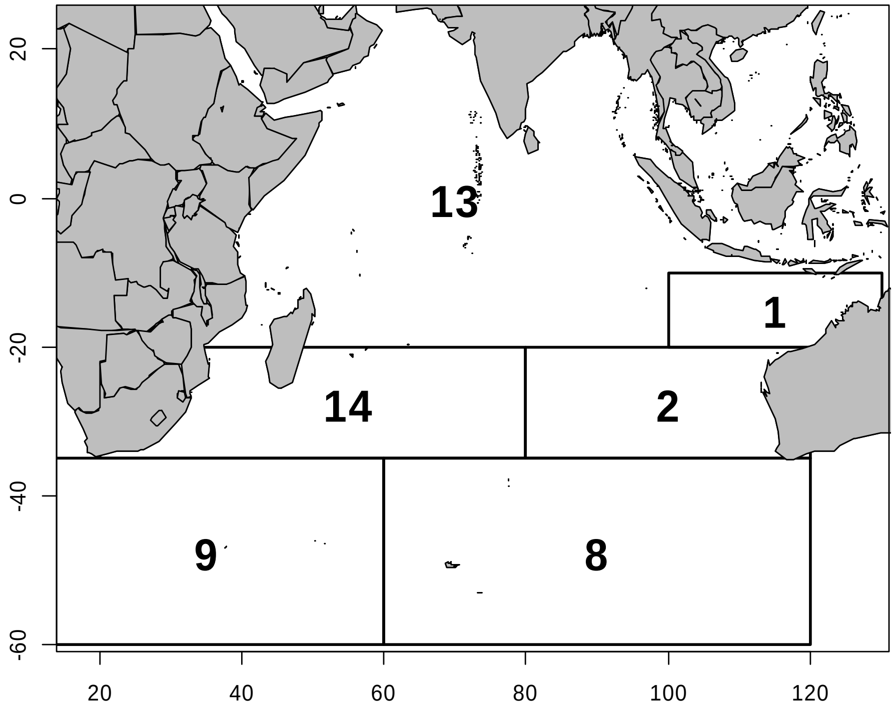

Fig. 1. The definition of CCSBT statistical areas.

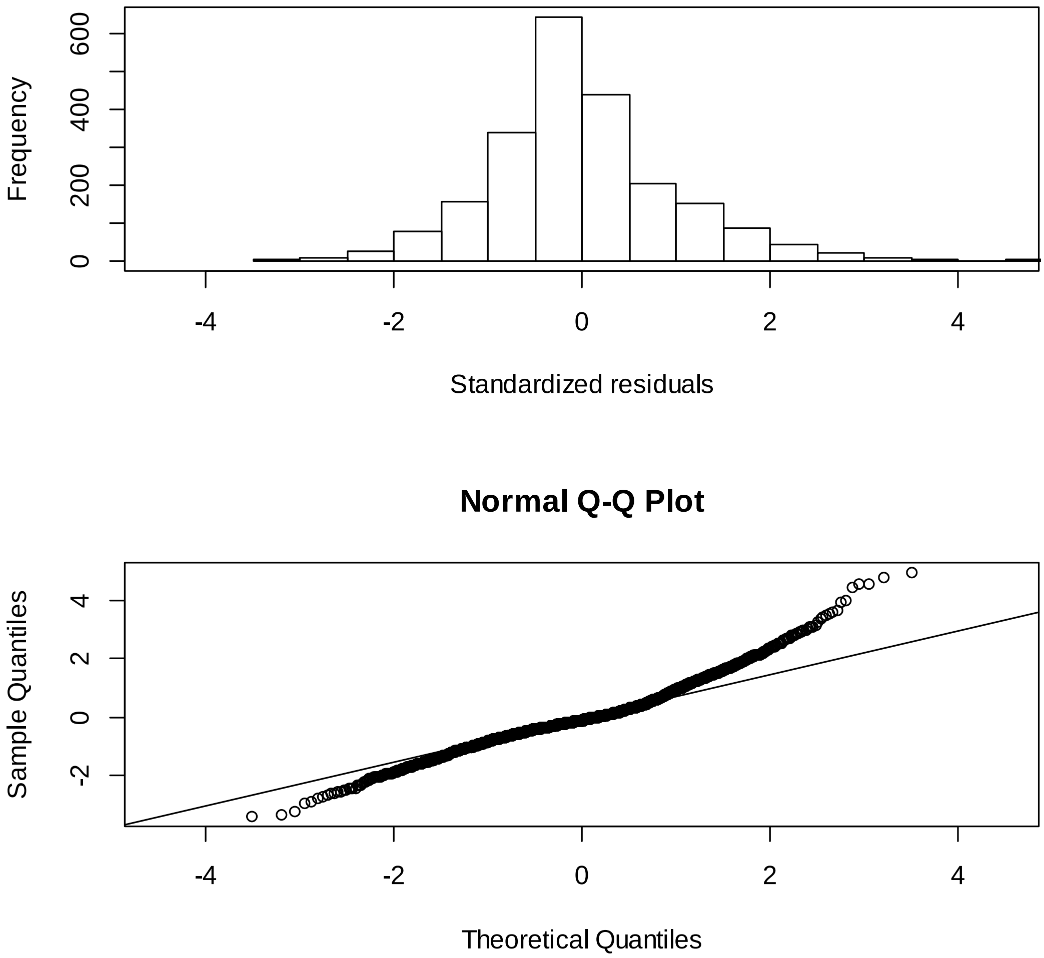

Fig. 2. The frequency distribution and Quantile-Quantile Plot for standardized residuals obtained from GLM analysis.

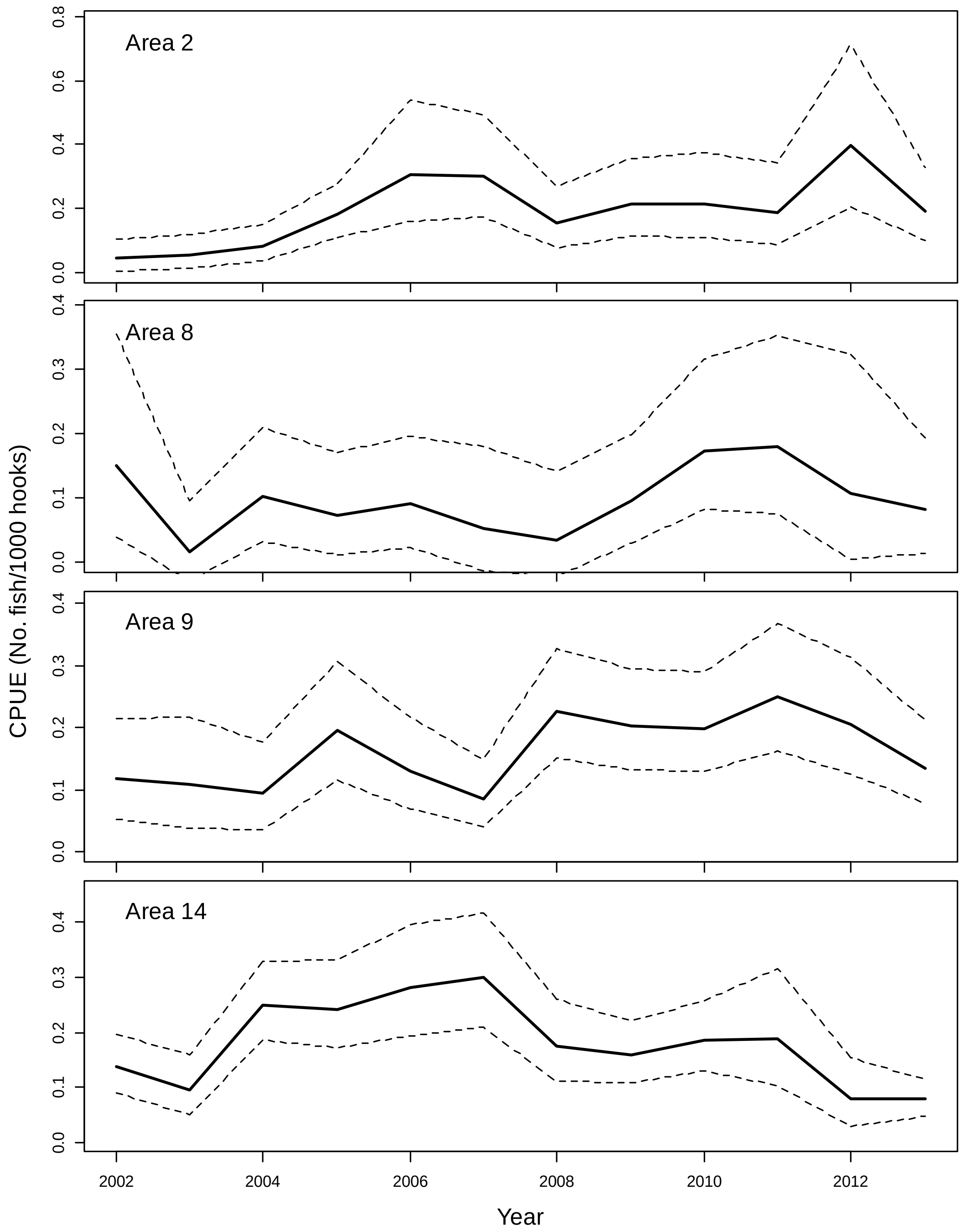

Fig. 3. Standardized CPUE of southern bluefin tuna caught by Taiwanese longline fishery. Dashed lines represents the 95% confidence intervals.

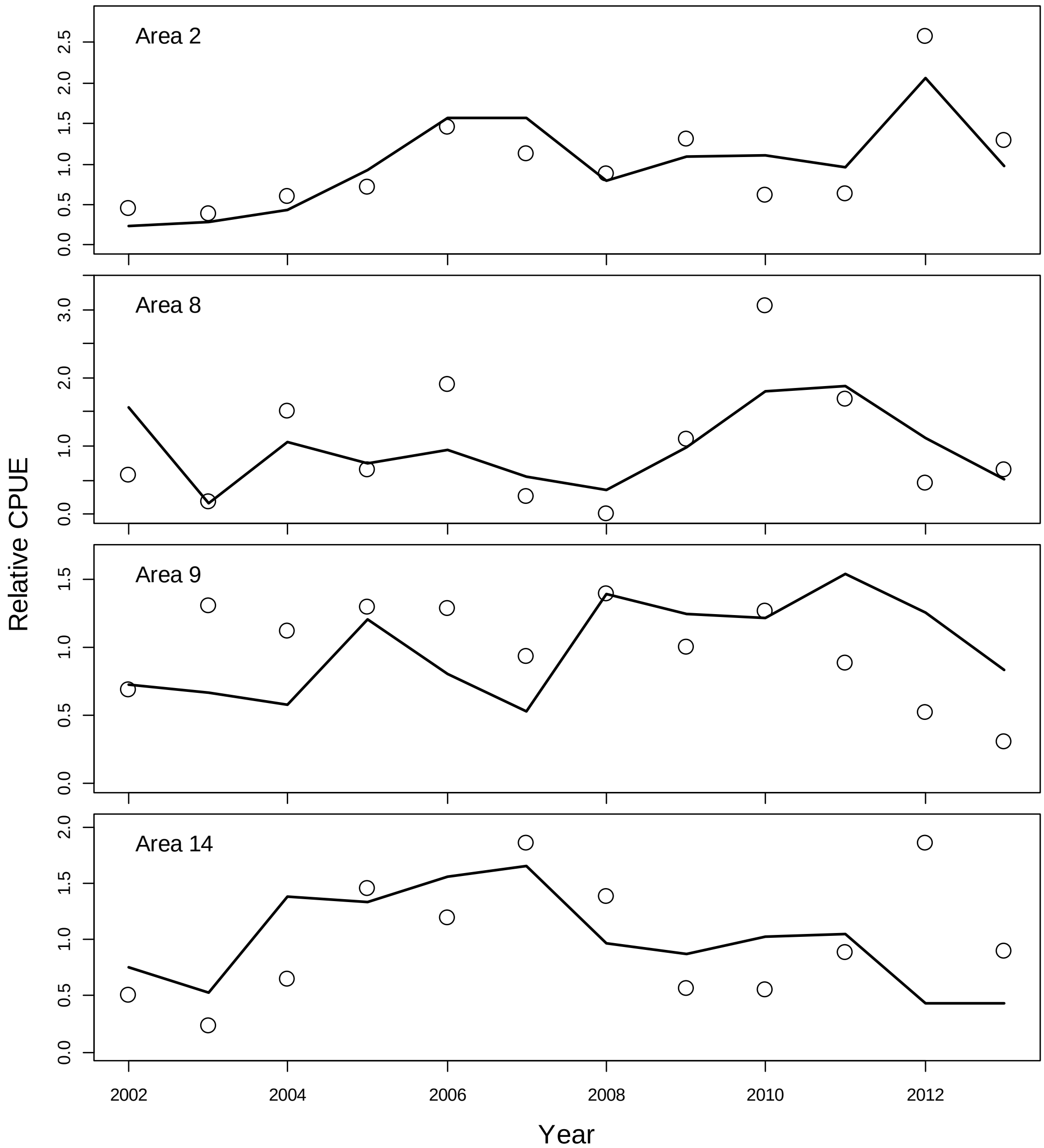

Fig. 4. Standardized (lines) and nominal (points) CPUE of southern bluefin tuna caught by Taiwanese longline fishery. CPUE was scaled by the average value for each area.