CPUE analysis for southern bluefin tuna caught by Taiwanese longline fleet

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ABSTRACT

This study attempts to select Taiwanese longline vessels which deployed more effort for catching southern bluefin tuna. Comparing to the amounts of catch and effort of all active longline vessels authorized to seasonally target SBT operating in the southern area of 20°S of the Indian Ocean, the results of vessel selections can exclude large amounts of efforts and keep relatively high proportion of SBT catches. The CPUE standardization is performed based on the data from selected vessels. Both of CCSBT statistical areas and Taiwanese SBT fishing grounds are adopted as the factors for GLM analysis. Standardized CPUEs generally reveal quite different trends for different area. It is apparent that the CCSBT statistical areas are not appropriate for Taiwanese SBT fleet since the main fishing grounds are separated into several parts by CCSBT statistical areas. It would be helpful to redefine CCSBT statistical areas for Taiwanese SBT fishery according to the temporal and spatial analysis of its fishing characters.

1. INTRODUCTION

Southern bluefin tuna (SBT) (*Thunnus maccoyii*) was by-catch of Taiwanese tuna longline fleet 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. However, large amount of vessels may not deploy their fishing effort for catching SBT even for vessels authorized to seasonally target SBT. This study attempts to extract the catch and effort data from the selected vessels which seasonally targeted SBT and deployed more effort for catching SBT. In addition, CPUE standardization of selected vessels are also performed to explore the trend of relative abundance index of SBT caught by Taiwanese longline fleet.

2. MATERIALS AND METHODS

2.1. Catch and Effort data

In this study, daily set-by-set catch and effort data (logbook) 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 2002-2011 are provided by Overseas Fisheries Development Council of Taiwan (OFDC).

2.2. Definition of fishing areas

Based on the catch and CPUE distribution of southern bluefin tuna caught by Taiwanese longline fleets (Anon, 2013), the fishing ground could be roughly divided into two areas: one is around the waters of the southern central Indian Ocean (Area1, in the area of 20°S-40°S and east of 50°E), and the other one is around the southeastern waters off South Africa (Area 2, in the area of 20°S-45°S and 20°E-50°E) (Fig. 1). In terms of sub-area used in the Taiwanese CPUE standardization, 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 is also adopted for the analysis of Taiwanese CPUE standardization (Fig. 2).

2.3. Vessel selection

In Taiwanese National Report and previous Taiwanese SBT CPUE analyses, the trend of SBT CPUE series were generally calculated based on the data from active longline vessels authorized to seasonally target SBT. In this study, the annual proportion of SBT catch to main species (albacore, bigeye tuan, yellowfin tuna, swordfish and SBT) are adopted as the criteria to select vessels and catch and effort data of these vessels are used to analyze CPUE trend. In this study, various vessel selection cases are conducted:

All SBT vessel: The data of all longline vessels that caught at least one SBT during a year in the Indian Ocean are used to analyze CPUE trend.

Case 10%-50%: The vessels, whose annual SBT catch proportion is less than 10, 20, 30, 40 and 50 percentiles of the annual SBT catch proportion of all SBT vessels, are excluded. The data of remaining vessels are used to analyze CPUE trend.

2.4. CPUE standardization

Based on the catch and effort data from selected vessels, general linear model (GLM) is applied to standardize the CPUE of SBT caught by Taiwanese longline fleet. The effects included in the models were year, month, fishing area, albacore and bigeye tuna CPUE and their interactions. However, 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) and thus this study include only interaction related to the year effect, i.e. the interaction between year and area, for further the area-specific CPUE standardization. The GLM is conducted as below:

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

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,
ε	is the error term, $\varepsilon \sim N(0, \sigma^2)$.

The effects of year, month and area are treated as categorical variables, while the effect of longitude, latitude and CPUEs of albacore and bigeye tuna are treated as continuous variables. The area-specific standardized CPUE trends are 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. Vessel selection

Table 1 shows the amount of selected vessels for various cases. The amount and percentage of exclusion of number of vessels increase when raising the vessel selection criterion. Generally, more 50% of vessels would be excluded from all SBT vessels when the criterion of SBT catch proportion is increased to more the 30 percentile of total SBT catch proportion (Tables 1 and 2).

Comparing to the case of all SBT vessels, the efforts (number of hooks) are substantially excluded for all vessel selection cases (Table 3). Comparatively, relative few amounts of SBT catch are excluded for all vessel selection cases (Table 4). Only about 7.1% of SBT catch are excluded when 26.5% of efforts are excluded. Even though more than 50% of efforts are excluded, about 20% of SBT catch are excluded. The results of vessel selections can exclude larger amount of effort and keep about more than 50% of SBT catch in the data sets. The results imply that large amount of efforts of active longline vessels authorized to seasonally target SBT operating in the

Indian Ocean did not deploy efforts for catching SBT. Therefore, the data extract from selected vessels would be more representative for further CPUE analysis. In this study, the data based on Case 10% is selected to perform the CPUE standardization analysis.

3.2 Summary of GLM statistics

Based on the GLM analysis, all of main effects and their interactions are statistically significant for using both of definition of sub-areas (Tables 5 and 6). When performing GLM based on CCSBT statistical areas, the factor of longitude (Lon) has much more explanatory ability than other factors, the second explanatory factor the factor of latitude (Lat). The most explanatory factor is the factor of latitude (Lat) and the secondaries are the factors of longitude (Lon) and area (A).

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 when GLM is performed based on incorporating the CCSBT statistical areas (Fig. 3). Similarly, the distribution of standardized residuals is close to the assumption of normal distribution when GLM is performed based on incorporating the definition of Taiwanese SBT fishing grounds (Fig. 4).

3.2. Trend of standardized CPUE

Fig. 5 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 in 2003, the standardized CPUE is Area 9 is much more stable than those in other areas. The standardized CPUE in Area 8 reveals increasing trend before 2010 but obviously decreased in 2011.

In this study, we also conducted a CPUE standardization analysis based on the definition of Taiwanese fishing grounds (Anon, 2013). Fig. 6 shows the area-specific standardized CPUE estimated based on incorporating Taiwanese SBT fishing grounds (Fig. 1). For Area A, trend of standardized CPUE increased before 2007 and decreased thereafter. For Area B, however, the trend of standardized CPUE is obviously distinct from that in Area A. CPUE trend reveals a substantially decreasing pattern during 2002-2004 and then became relatively table after 2005.

Based on the distributions of effort, catch and CPUE of SBT caught by Taiwanese SBT fleet, however, the main SBT fishing grounds are separated into several parts by CCSBT statistical areas (Figs. 7 and 8).Therefore, the definition of CCSBT statistical areas is not appropriate to be adopted for the CPUE analysis of SBT caught by Taiwanese SBT fleet. It would be helpful to redefine the CCSBT statistical areas for Taiwanese SBT fishery according to the temporal and spatial analysis of its fishing characters.

Acknowledgments

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Table 1. Number of selected vessels for various cases.

Year	ALL SBT vessel	Case10%	Case20%	Case30%	Case40%	Case50%
2002	59	42	32	26	21	19
2003	83	61	47	36	27	24
2004	89	64	46	38	31	27
2005	51	42	32	28	22	18
2006	32	30	24	19	12	7
2007	29	23	21	19	10	2
2008	36	32	24	17	12	10
2009	57	34	31	24	18	12
2010	71	67	63	53	47	32
2011	43	31	27	21	16	11

Table 2. Percentage of exclusion of number of vessels for various cases comparing to the case that all SBT vessels are selected.

Year	Case10%	Case20%	Case30%	Case40%	Case50%
2002	28.8	45.8	55.9	64.4	67.8
2003	26.5	43.4	56.6	67.5	71.1
2004	28.1	48.3	57.3	65.2	69.7
2005	17.6	37.3	45.1	56.9	64.7
2006	6.3	25.0	40.6	62.5	78.1
2007	20.7	27.6	34.5	65.5	93.1
2008	11.1	33.3	52.8	66.7	72.2
2009	40.4	45.6	57.9	68.4	78.9
2010	5.6	11.3	25.4	33.8	54.9
2011	27.9	37.2	51.2	62.8	74.4
Average	21.3	35.5	47.7	61.4	72.5

Table 3. Percentage of exclusion of effort (number of hooks) for various cases comparing to the case that all vessels are selected.

Year	Case10%	Case20%	Case30%	Case40%	Case50%
2002	44.2	64.7	78.4	88.5	92.9
2003	40.9	60.6	74.3	81.7	84.4
2004	45.7	69.7	76.8	82.2	85.3
2005	24.7	52.2	62.5	73.5	77.9
2006	6.0	30.5	49.9	68.7	81.5
2007	18.6	27.8	35.4	69.5	93.9
2008	13.8	35.6	56.2	69.2	71.8
2009	35.7	41.4	57.4	68.9	80.7
2010	7.3	13.3	27.3	36.6	57.2
2011	28.6	40.9	59.8	70.7	84.5
Average	26.5	43.7	57.8	71.0	81.0

Table 4. Percentage of exclusion of catch (number of fishes) using different criteria comparing to the case that all vessels are selected.

Year	Case10%	Case20%	Case30%	Case40%	Case50%
2002	16.7	38.2	57.7	70.8	77.8
2003	15.9	33.4	51.3	64.5	68.9
2004	19.2	42.4	53.2	62.3	68.6
2005	7.9	25.6	34.5	47.6	56.4
2006	0.1	21.2	34.9	57.4	78.2
2007	3.1	4.9	15.4	54.8	89.0
2008	2.8	23.7	40.9	61.2	68.1
2009	3.0	3.6	16.1	38.1	59.5
2010	0.2	3.6	12.3	20.9	38.7
2011	1.7	10.4	28.9	52.5	72.4
Average	7.1	20.7	34.5	53.0	67.8

Table 5. ANOVA table for GLM analysis based on incorporating the CCSBT statistical areas.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	98	56694.15	578.51	335.05	<.0001
Error	49605	85651.33	1.73		
Corrected Total	49703	142345.49			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.40	-141.35	1.31	-0.93

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	9	318.07	35.34	20.47	<.0001
M	11	938.33	85.30	49.40	<.0001
A	3	636.79	212.26	122.93	<.0001
Lon	1	2472.17	2472.17	1431.76	<.0001
Lat	1	864.40	864.40	500.62	<.0001
BET	1	27.39	27.39	15.86	<.0001
ALB	1	11.63	11.63	6.74	0.0095
Y*A	27	3099.93	114.81	66.49	<.0001
Lon*M	11	1758.33	159.85	92.58	<.0001
Lat*M	11	1064.35	96.76	56.04	<.0001
BET*M	11	348.58	31.69	18.35	<.0001
ALB*M	11	565.40	51.40	29.77	<.0001

Table 6. ANOVA table for GLM analysis based on incorporating the definition of Taiwanese SBT fishing grounds.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	78	55247.39	708.30	403.56	<.0001
Error	49625	87098.10	1.76		
Corrected Total	49703	142345.49			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.3881	-142.51	1.32	-0.93

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	9	547.14	60.79	34.64	<.0001
M	11	1182.69	107.52	61.26	<.0001
A	1	598.11	598.11	340.78	<.0001
Lon	1	696.35	696.35	396.75	<.0001
Lat	1	1776.73	1776.73	1012.31	<.0001
BET	1	13.53	13.53	7.71	0.0055
ALB	1	8.54	8.54	4.86	0.0274
Y*A	9	1789.87	198.87	113.31	<.0001
Lon*M	11	2571.44	233.77	133.19	<.0001
Lat*M	11	1387.20	126.11	71.85	<.0001
BET*M	11	370.13	33.65	19.17	<.0001
ALB*M	11	614.94	55.90	31.85	<.0001

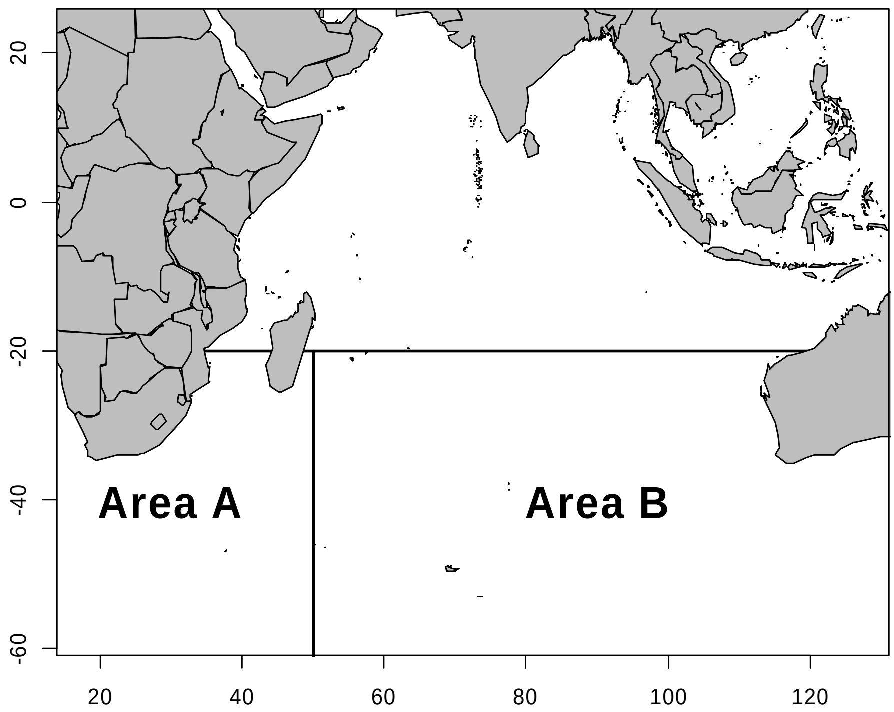

Fig 1. The definition of two fishing grounds of southern bluefin tuna for Taiwanese fleets operated in the Indian Ocean.

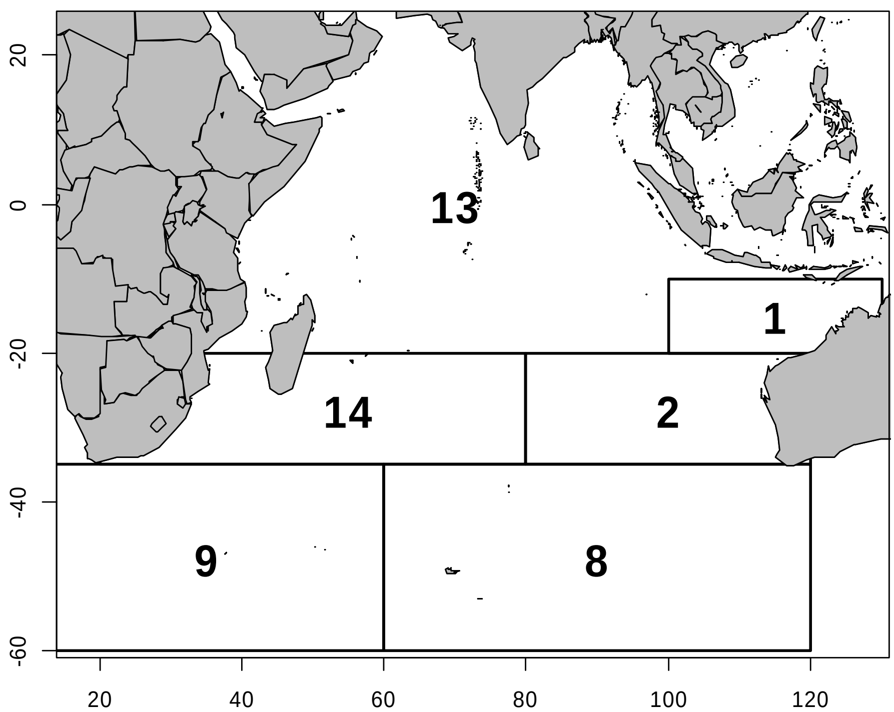

Fig. 2. The definition of CCSBT statistical areas.

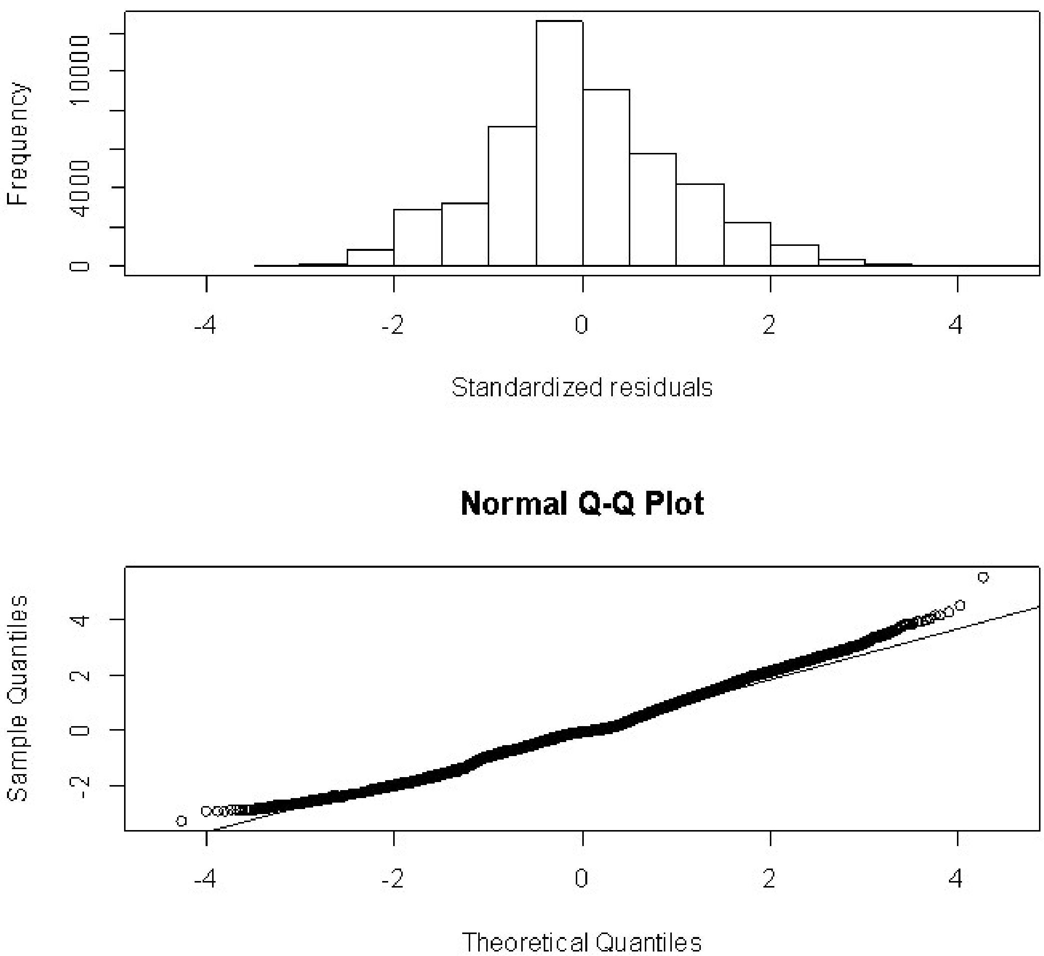

Fig. 3. The frequency distribution and Quantile-Quantile Plot for standardized residuals obtained from GLM analysis based on incorporating the CCSBT statistical areas.

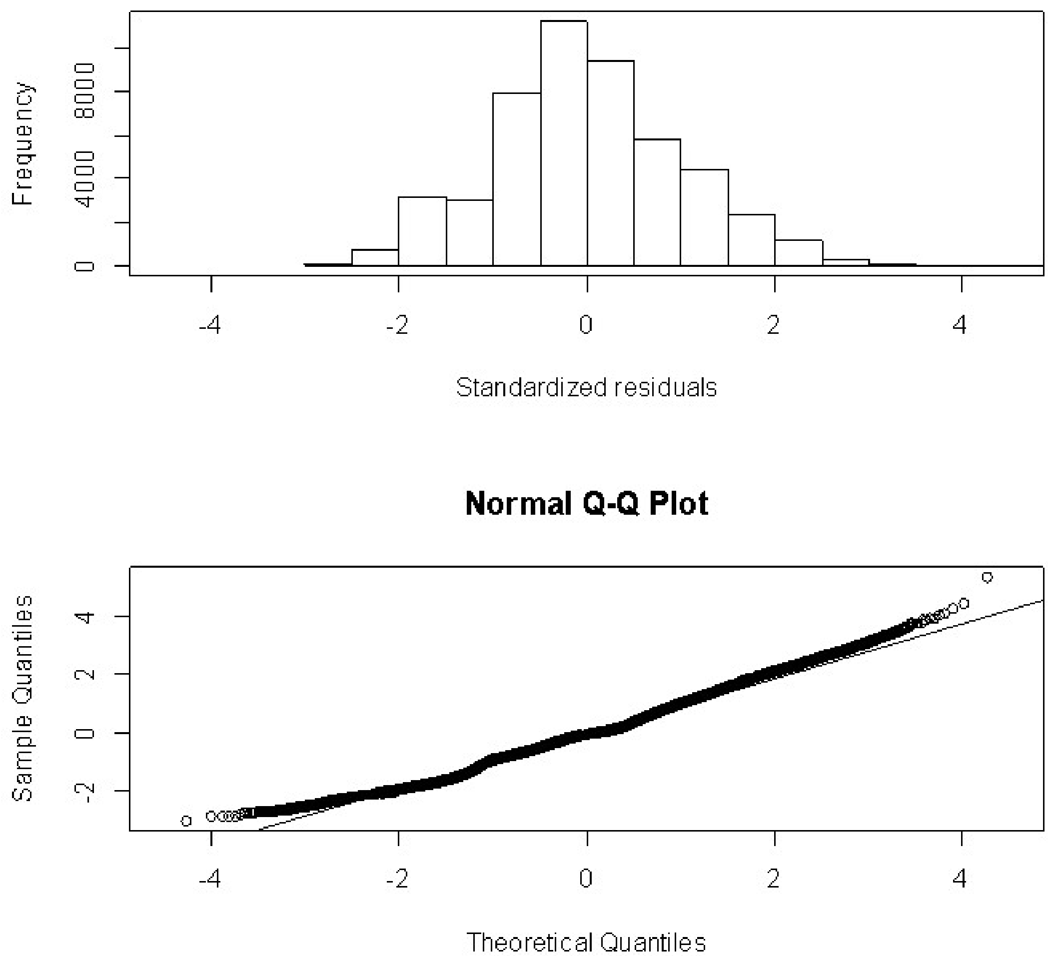

Fig. 4. The frequency distribution and Quantile-Quantile Plot for standardized residuals obtained from GLM analysis based on incorporating the definition of Taiwanese SBT fishing grounds.

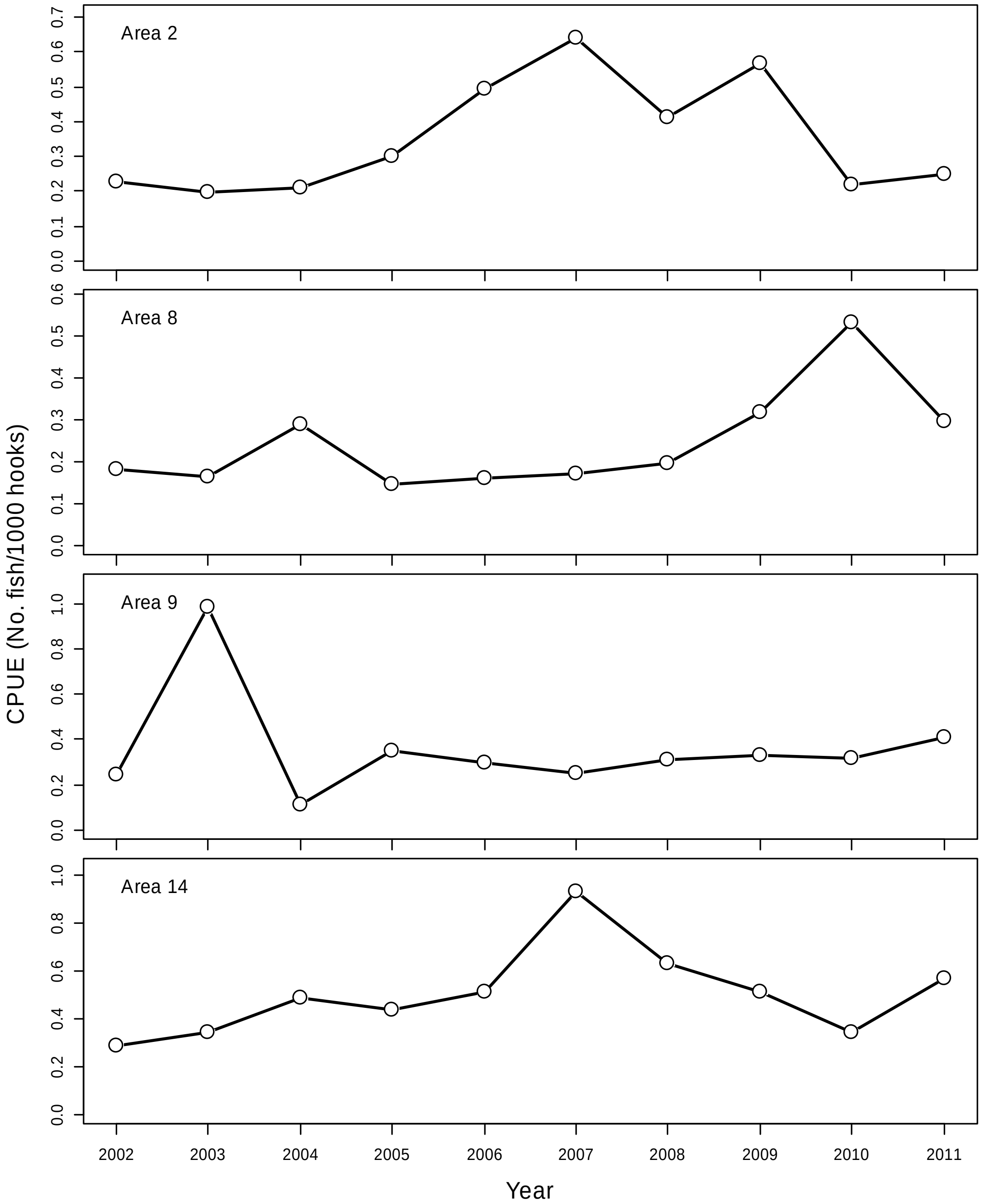

Fig. 5. Standardized CPUE of southern bluefin tuna caught by Taiwanese longline fleet estimated based on incorporating the definition of CCSBT statistical areas.

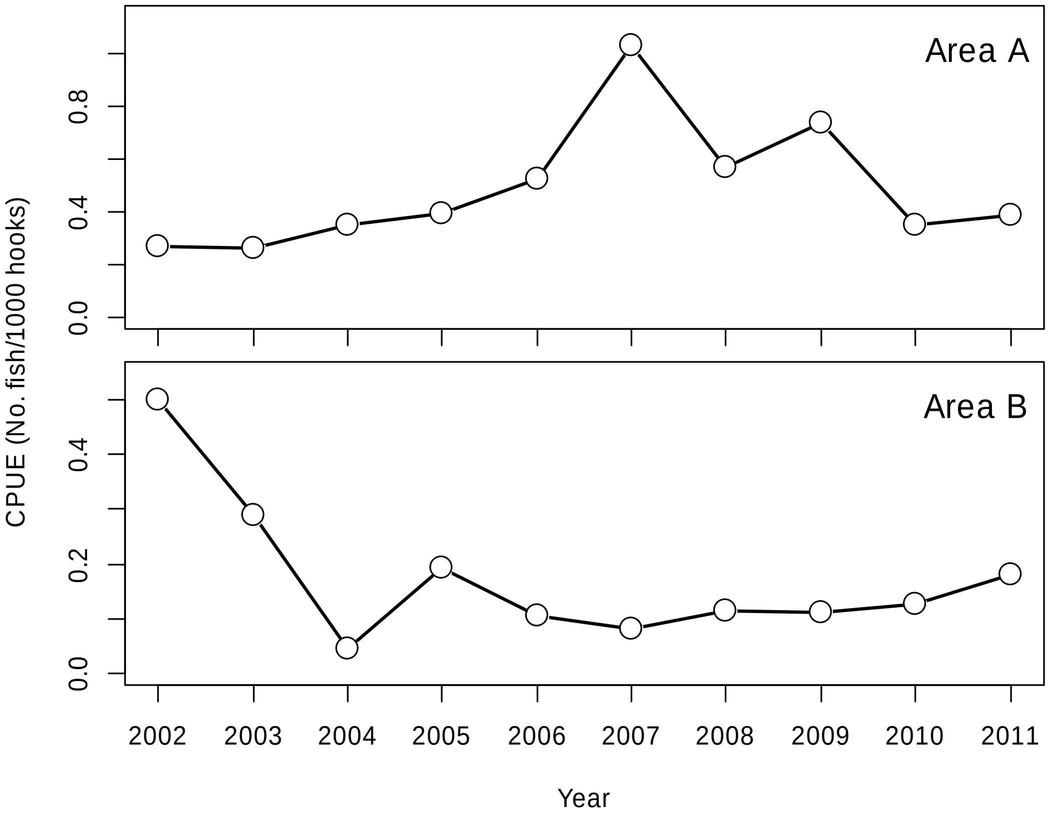

Fig. 6. Standardized CPUE of southern bluefin tuna caught by Taiwanese longline fleet estimated based on incorporating the definition of Taiwanese SBT fishing grounds.

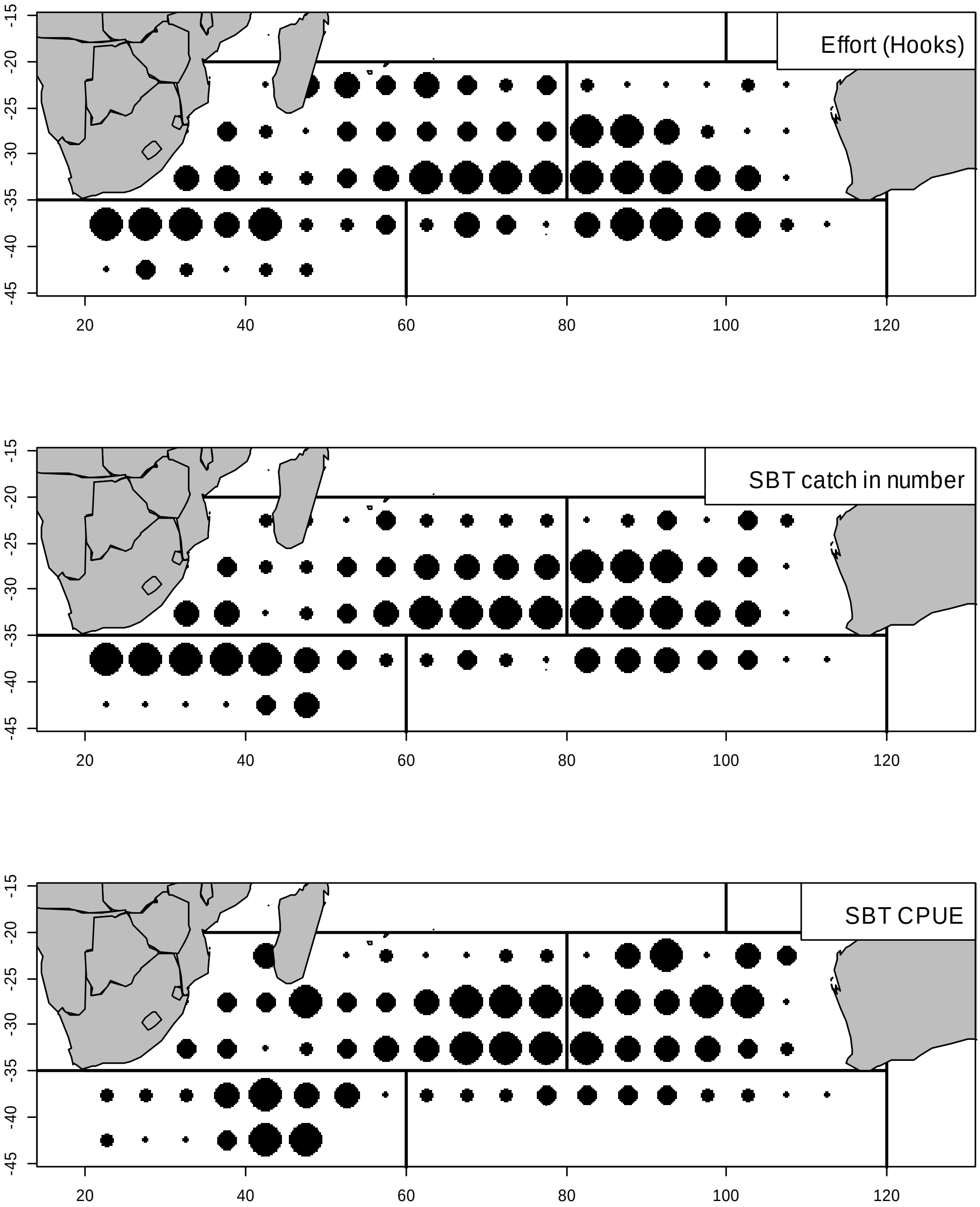

Fig. 7. The distributions of effort, catch and CPUE of SBT caught by Taiwanese SBT fleet. The circles represent the aggregated amounts during 2002-2011.

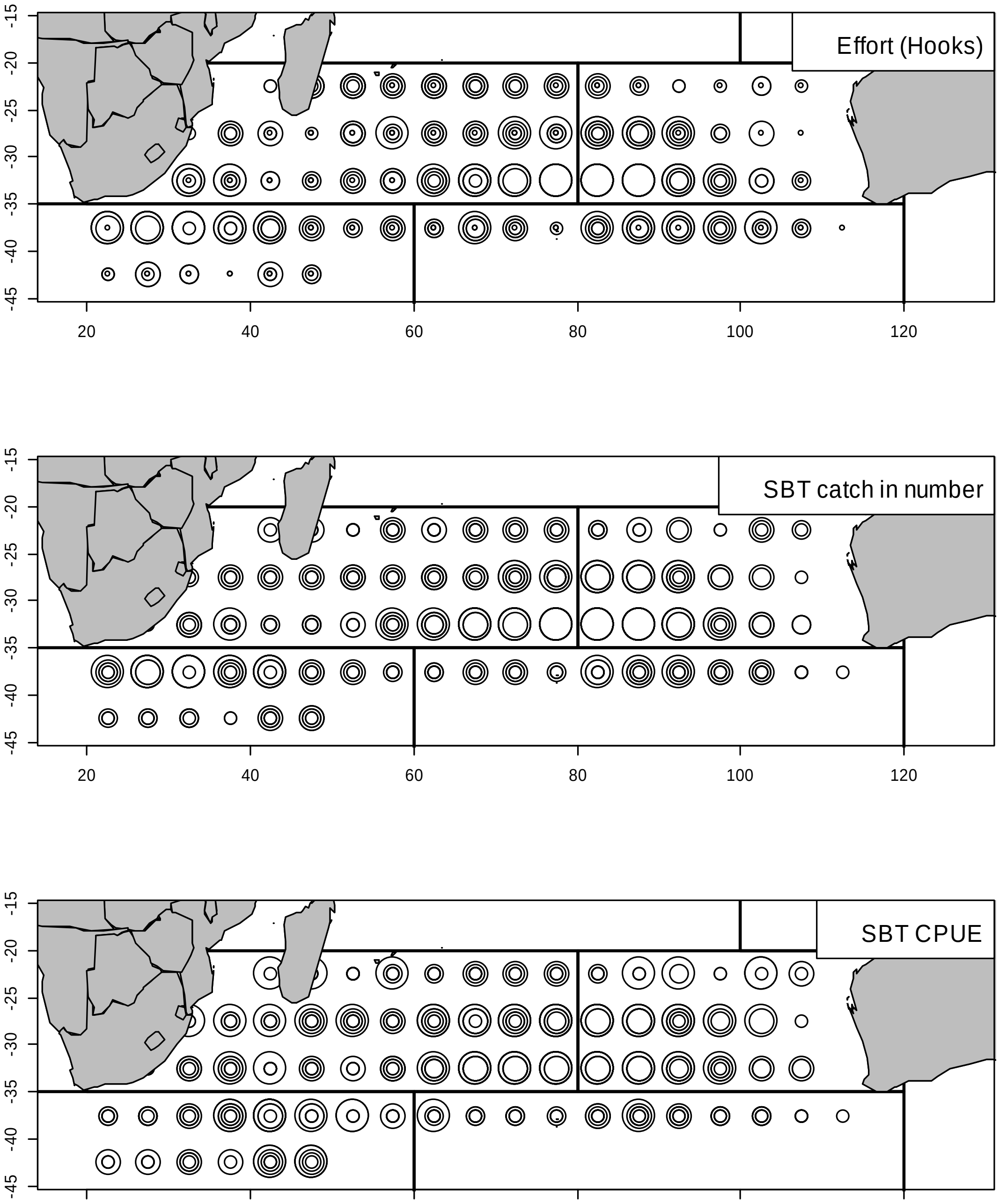

Fig. 8. The distributions of effort, catch and CPUE of SBT caught by Taiwanese SBT fleet. The overlapped circles represent the annual amounts during 2002-2011.