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Updated CPUE standardizations for Bigeye tuna caught by Taiwanese longline fishery in the Indian Ocean using generalized liner model

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1 Introduction

1.1 Historical development of Taiwanese longline fishery in the Indian Ocean

Taiwan began to develop distant water tuna longline fisheries in the mid-60s. Early distant water operations targeted albacore and yellowfin for export to foreign canneries. Until the early 80s, Taiwanese tuna longline fishery expanded the ultra-low freezing technology (ULT) tuna operations. Bigeye and yellowfin are the major species caught by the ULT tuna longliners, while albacore is still a major target species for a large Taiwan fleet in the Indian Ocean longline (Haward and Bergin 2000).

Bigeye tuna, *Thunnus obesus*, is the most valuable and cosmopolitan scombridae, distributing in the tropical and temperate waters (Collette and Nauen, 1983). In the Indian Ocean, Taiwanese tuna longline fishery targeting bigeye tuna mainly distributes in the tropical regions, between 15°N and 15°S. The production of the entire Indian bigeye tuna stock has exceeded 100,000 mt since 1993, has reached the highest catch 152,000 mt at 1999, then decreased gradually to 71,000 mt in 2010. Taiwanese catches have been accounted to around 20%-40% since 1979.

There was an observable change when Taiwanese longline fishing activities shifted target species from albacore to bigeye. Looking into the history of bigeye tuna longline fishing in the Indian Ocean, prior to the late 80s, the average catch recorded around 6,000 mt. As a result of a shift of target species from albacore to bigeye, the bigeye catch started increasing to the highest level, 60,000 mt in 2003. However, this number was not maintained. Total annual bigeye tuna catches by Taiwanese longline fishery averaged 24,000 t over the period 2008 to 2010 and the 2010 catch was 17,700 t (Figure 1). During the last two years, the fishery has been moving off the coast of Somalia due to active piracy in the area. It turned out that the bigeye catch being taken in western Indian Ocean form a smaller percentage of the total catch in 2010 (50%) than the previous years (74% for 2008-2009 and 81% for 2000-2007).

1.2 The bigeye tuna status in the Indian Ocean

The mean bigeye tuna catch over the 2007-2009 period of 111,000 t is in the middle of MSY level (95,000-183,000 t). According to the results of stock assessment held in the previous IOTC workshop (IOTC, 2010), the stock is probably not overfished, and overfishing is probably not occurring. However, the bigeye catches should be kept at or lower than the 2009 level to on the basis of the estimated uncertainty and the continuing observed decline in CPUE.

1.3 Summary of the previous CPUE standardizations for bigeye tuna caught by Taiwanese longline fishery in the Indian Ocean

For stock assessment purposes, the standardizations of CPUE for Bigeye tuna caught by Taiwanese longline fishery in the Indian Ocean were conducted by generalized linear mixed model (GLMM) based on aggregated monthly catch and effort data with 5 degree by 5 degree resolution from 1968 to 2004 and daily set by set catch and effort data (logbook data set) with 5 degree by 5 degree resolution from 1979 to 2004 (Hsu, 2006). Data manipulation was included in this previous study to screen the logbook data set. The adjustment was adopted to deal with some records with unreasonable large number of hooks.

For understanding the environmental influence on CPUE variations, the standardizations of CPUE for Bigeye were carried out based on daily set-by-set catch and effort data with 1 degree by 1 degree resolution from 1995 to 2008 (Chang and Yeh, 2009). The environmental data were provided Japanese scientist. The environmental data includes the moon phase by day, Shear current and its amplitude, thermo-cline depth, temperature and salinity at depth of 205 m (205 m is the representative depth where bigeye are caught by LL), IOI, SOI and Di pole index (DPI). The significant environment factors were IOI, thermo-cline depth, temperature at depth of 205 m and amplitude of the shear current (Chang and Yeh, 2009).

1.4 Purpose of the study

To provide an update of indices of abundance for bigeye tuna from the Taiwanese longline fishery presented for the period 1979-2009.

2 Material and Method

In this study, the researchers follow the procedure adopted in previous study (Yeh et al. 2010) but with recent data updates and some adjustments. Compare to the previous study, the principle of data extraction is replaced by the following rules: (1). Main target species are all zero catches; (2). The number of hooks per set are less than 1,000 hooks or are larger than 5,000 hooks; and (3). The location of fishing operation is beyond the concerned area (Figure 2).

2.1 Data set

In this study, daily set-by-set catch and effort data with 5 degree by 5 degree resolution from the logbooks of Taiwanese longline fishery from 1979-2010 and daily set-by-set catch and effort data with 1 degree by 1 degree resolution from the logbooks of Taiwanese longline fishery from 1995-2010 were provided by Overseas Fisheries Development Council (OFDC). In addition, the data on the number of hooks between floats (NHBF) were available since 1995, and the percentage of data with NHBF was about 80% of the total data from 1995 to 2010. To obtain a longer series for bigeye stock assessment, therefore we use the species composition to be a target proxy to consider the effects of target species shifts issue.

2.2 Statistical models

Statistical models of GLM were used to model the logarithm of the nominal CPUE (defined as the number of fish per 1,000 hooks) in this study. The main factors considered in this study are year, month, area (Areas 1 to 9, defined in Figure 2), and target species. The interactions between the main factors are also included in the model. The information of NHBF was only available from 1995 onwards in the logbooks of Taiwanese longline fishery. Therefore, the information of NHBF was used to determine the target proxy in the CPUE standardization models. According to the analysis of the relationship between the NHBF and catch composition, the target proxy is defined as follows:

1. Three categories of Albacore catch composition (catch of Albacore / catch of Bigeye, Yellowfin and Albacore) are defined as, 1: <=13%; 2:13%-39%; 3: >39%.
2. Three categories of Yellowfin tuna catch composition (catch of Yellowfin / catch of Bigeye, Yellowfin and Albacore) are defined as, 1: <=20%; 2:20%-35%; 3: >35%.

We used six GLM models for six nominal CPUE series: annually and quarterly data in 5x5 grid resolution for the whole Indian Ocean (Area1 – Area 9), tropical Indian Ocean (Area 1 - Area 5) and South Area (Area 6 and Area 7) from 1979 to 2010.

GLM model: The CPUE is predicted as a linear combination of the explanatory variables. At first, the following form was assumed as a full model.

$$\log(\mathrm{CPUE} + \mathrm{c}) = \mu + \mathrm{Y} + \mathrm{M} + \mathrm{A} + \mathrm{T} + \mathrm{interactions} + \varepsilon$$

where *CPUE* is the nominal CPUE of bigeye tuna,
c is the constant value (0.1),
μ is the intercept,
Y is the effect of year,
M is the effect of month,
A is the effect of fishing area,
T is the Target proxy,
Interactions is the interactions between main effects,
ε is the error term, $\varepsilon \sim N(0, \sigma^2)$.

Fishing areas used in this study were defined b nine areas based on the IOTC statistics areas for bigeye tuna in the Indian Ocean (Fig. 2):

1. Area 1: The open sea off the Somalia;
2. Area 2: The waters around the Maldives;
3. Area 3: The waters around the Seychelles;
4. Area 4: The waters around the Chagos Archipelago;
5. Area 5: The western Tropical Area ;
6. Area 6: Mozambique Channel;
7. Area 7: The open sea off the Australia;
8. Area 8: Arabian Sea and Bay of Bengal ;
9. Area 9:.The waters near the sub-Antarctic.

2.3 Statistical runs

This study has conducted a set of standardization runs using logbook data by GLM models. All runs only keep significant factors ($p<0.0001$) in the analysis of CPUE by the effective effort. The calculation was done using GLM and MIXED procedure of SAS (Ver.9. 2). The standardized CPUE were then computed from the least square means (LSMeans) of the estimates of the year effects and quarterly effects.

3 Results and Discussion

Since Taiwanese logbook data is preliminary in 2010, lack of information in several months happened. It turns out some difficulty in parameter estimation in GLM analysis. Therefore, the 2010 logbook data was excluded in this study.

Table 1 show the ANOVA tables for the annual-based GLM analyses for the whole Indian Ocean, the tropical Indian Ocean, and the South Area, separately. The R squares for the model of all runs were around 0.3. The RALB factors, as a target proxy, explained relatively large amount of variance for the whole Indian Ocean and the South area. For the Tropical Area, the RYFT, also as a target proxy, explained relatively large amount of variance.

Annually nominal and standardized CPUEs obtained from GLMs for are shown for the whole Indian Ocean, the tropical Indian Ocean, and the Tropical Area separately in Fig. 3-5. Relative standardized CPUE series for all three cases show similar decreasing trends from 2003. Distributions of the standardized residuals and the qqplots for annually-based GLMs are showed in Fig. 9-14. All cases appear to deviate slightly from normal distribution and show some extent of divergence for left tail. However, they are not statistically significant different with normal distribution.

Table 1. ANOVA table of GLM for yearly based CPUE for Whole Indian Ocean (Above), Tropical Area (Middle), and South Area (Bottom) from 1979 to 2009.

Whole Indian Ocean

Source	DF	Sum of Squares	Mean Square	F-value	P-value
Model	309	257631.5662	833.7591	1001.94	<.0001
Error	499631	415765.9949	0.8321		
Corrected Total	499940	673397.5611			
	R-Square	Coeff Var	Root MSE	LnCPUE Mean	
	0.382585	74.14134	0.912220	1.230380	
Source	DF	Type III SS	Mean Square	F-value	P-value
year	30	4515.49222	150.51641	180.88	<.0001
Area	6	7359.92777	1226.65463	1474.09	<.0001
mon	11	2330.30037	211.84549	254.58	<.0001
ralb	2	40343.85341	20171.9267	24240.8	<.0001
ryft	2	34460.73535	17230.36767	20705.9	<.0001
year*Area	180	7413.54188	41.18634	49.49	<.0001
Area*mon	66	6581.30407	99.71673	119.83	<.0001
Area*ryft	12	2173.95068	181.16256	217.71	<.0001

Tropical Area

Source	DF	Sum of Squares	Mean Square	F-value	P-value
Model	221	114929.7655	520.0442	682	<.0001
Error	426134	324938.3319	0.7625		
Corrected Total	426355	439868.0975			
	R-Square	Coeff Var	Root MSE	LnCPUE Mean	
	0.261282	61.40339	0.873227	1.422116	
Source	DF	Type III SS	Mean Square	F-value	P-value
year	30	3294.44303	109.81477	144.01	<.0001
Area	4	421.01418	105.25355	138.03	<.0001
mon	11	406.64203	36.96746	48.48	<.0001
ralb	2	25190.7674	12595.3837	16518	<.0001
ryft	2	41103.18957	20551.59479	26952	<.0001
year*Area	120	4810.51284	40.08761	52.57	<.0001
Area*mon	44	1601.49277	36.39756	47.73	<.0001
Area*ryft	8	904.69163	113.08645	148.31	<.0001

South Area

Source	DF	Sum of Squares	Mean Square	F-value	P-value
Model	87	37042.7178	425.7784	347.72	<.0001
Error	73497	89996.8941	1.2245		
Corrected Total	73584	127039.6119			

	R-Square	Coeff Var	Root MSE	LnCPUE Mean
	0.291584	926.3774	1.106570	0.119451

Source	DF	Type III SS	Mean Square	F-value	P-value
year	30	2796.548	93.21827	76.13	<.0001
Area	1	63.75578	63.75578	52.07	<.0001
mon	11	4836.64705	439.69519	359.08	<.0001
ralb	2	16061.85209	8030.92605	6558.55	<.0001
ryft	2	7946.81334	3973.40667	3244.93	<.0001
year*Area	30	962.59974	32.08666	26.2	<.0001
Area*mon	11	242.15894	22.01445	17.98	<.0001

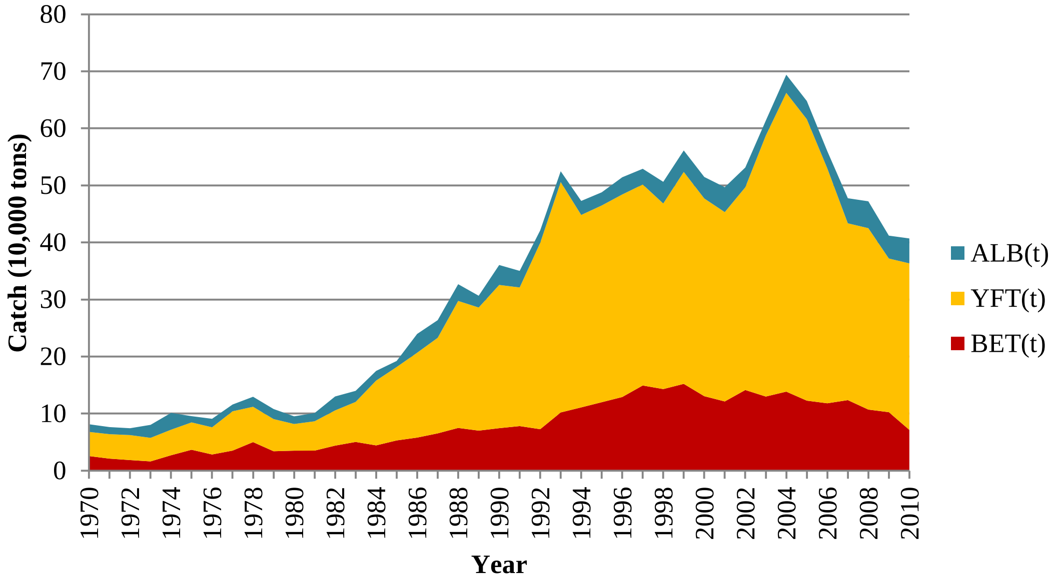

Figure 1. Nominal catches (metric tons) of main target species caught by Taiwanese longline fishery in the Indian Ocean over the period 1970 to 20010.

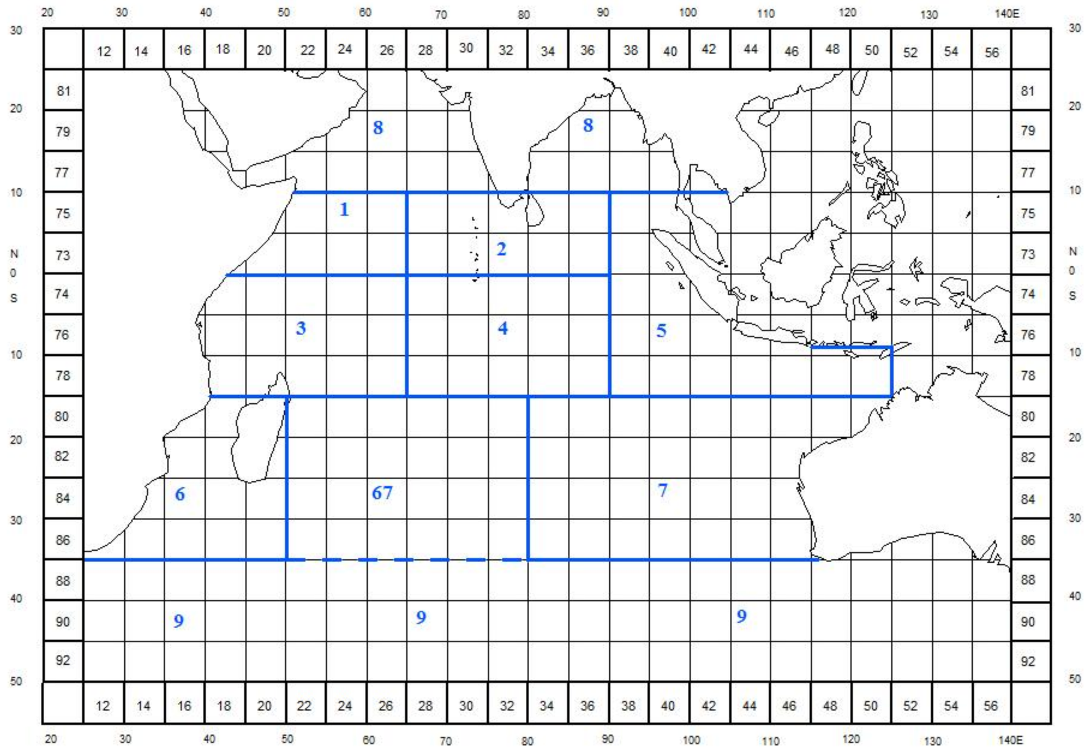

Figure 2. Area stratification used for the standardization of CPUE for bigeye tuna in the Indian Ocean in 2010.

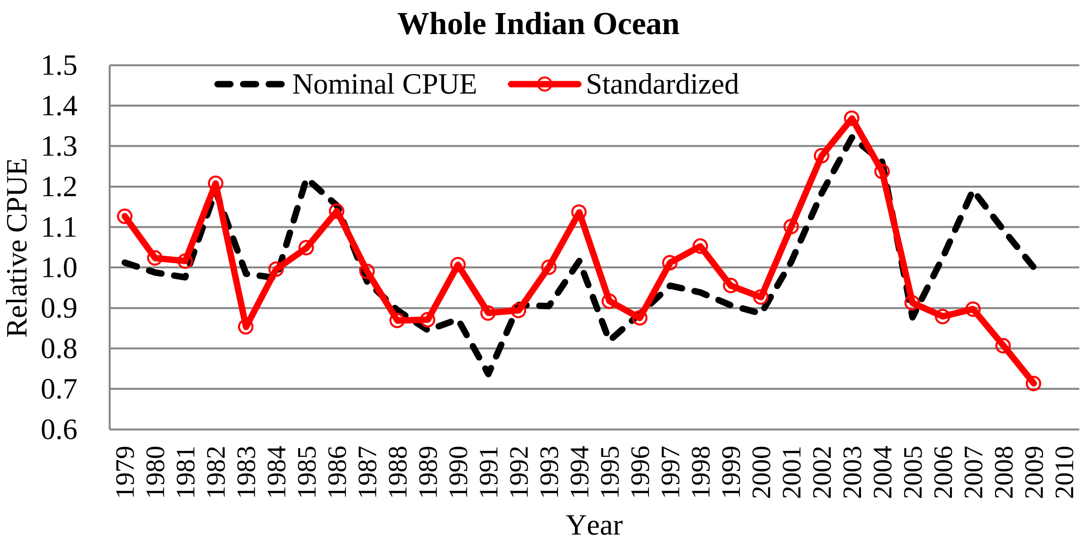

Figure 3. Relative nominal and standardized annually CPUE series for the whole Indian Ocean from 1979 to 2009.

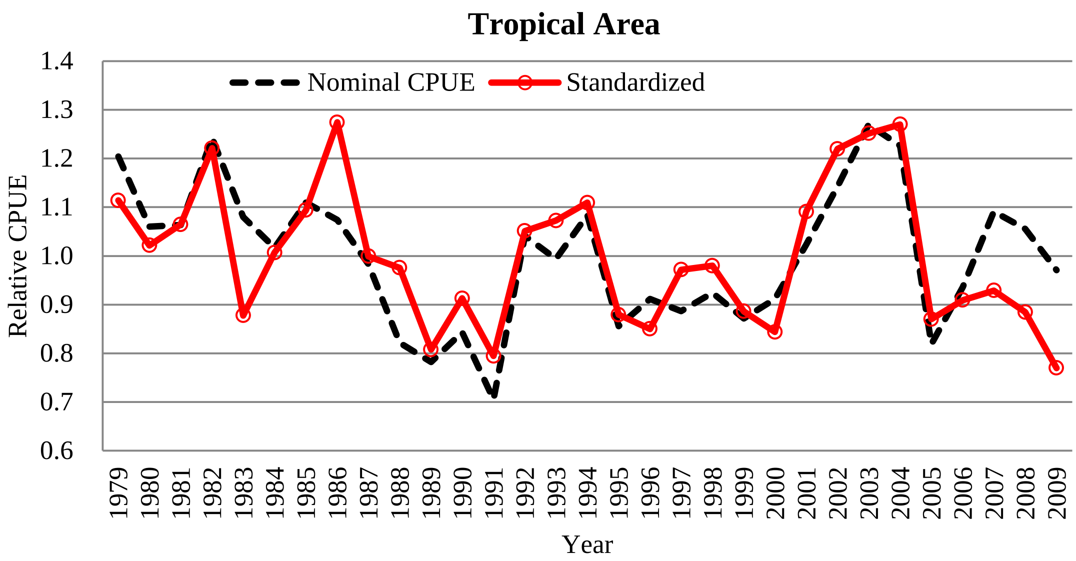

Figure 4. Relative nominal and standardized annually CPUE series for the tropical Indian Ocean from 1979 to 2009.

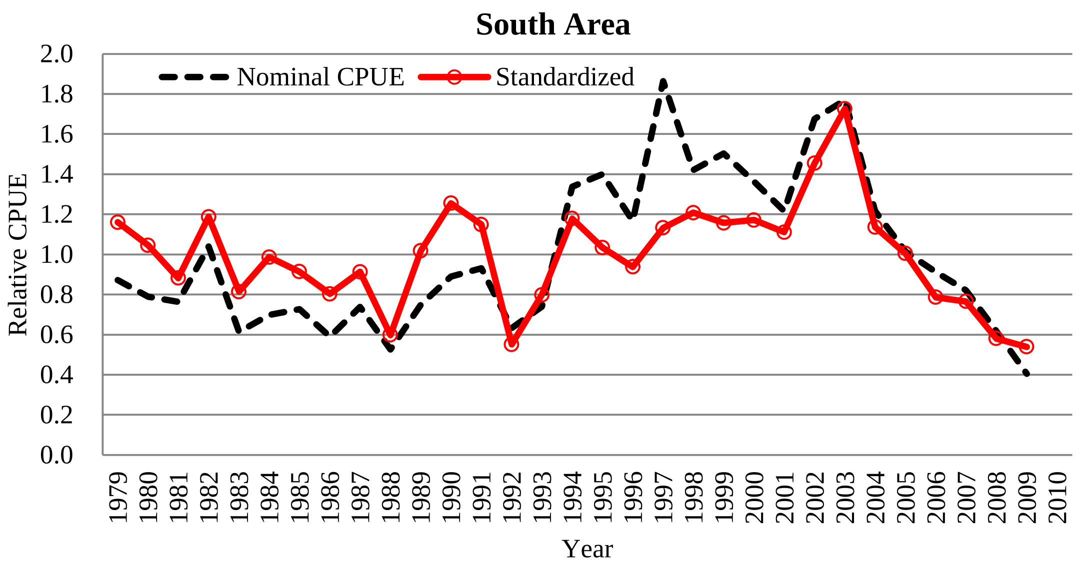

Figure 5. Relative nominal and standardized annually CPUE series for the South Area from 1979 to 2009.

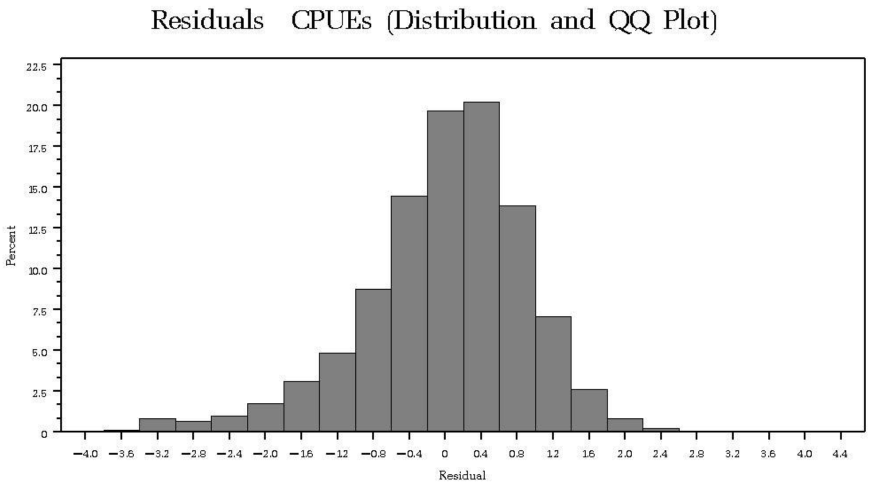

Figure 6. The residuals distribution of annual based CPUE standardization for the whole Indian Ocean from 1979 to 2009.

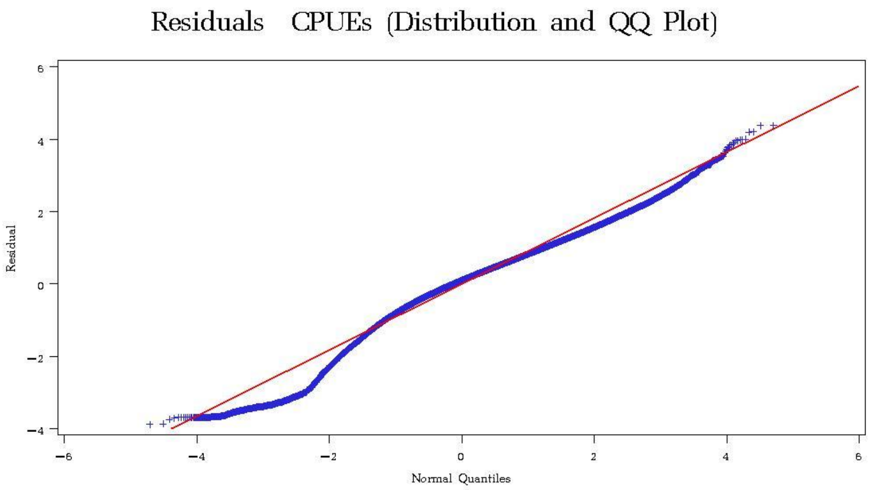

Figure 7. The QQPlot of annual based CPUE standardization for the whole Indian Ocean from 1979 to 2009.

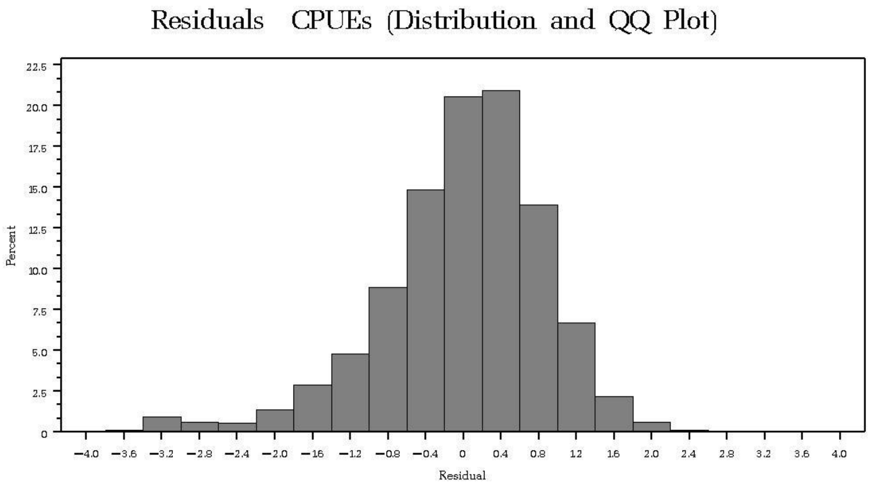

Figure 8. The residuals distribution of annual based CPUE standardization for the tropical Indian Ocean from 1979 to 2009.

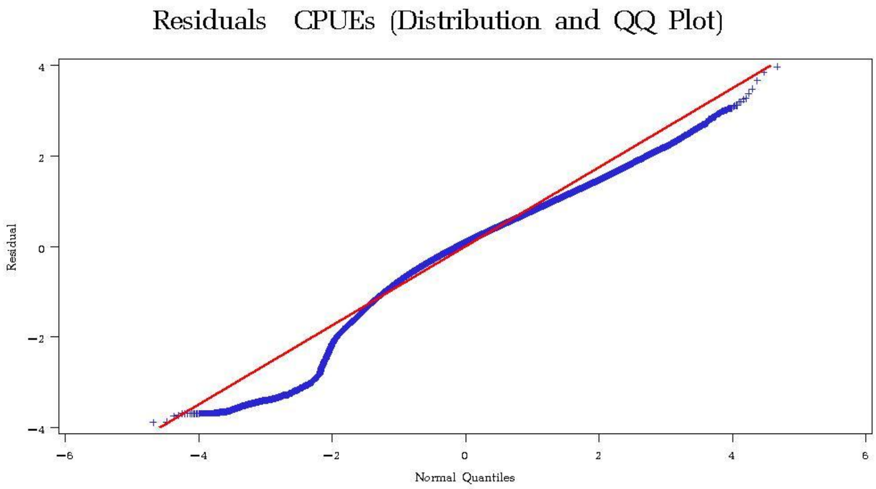

Figure 9. The QQPlot of annual based CPUE standardization for the tropical Indian Ocean from 1979 to 2009.

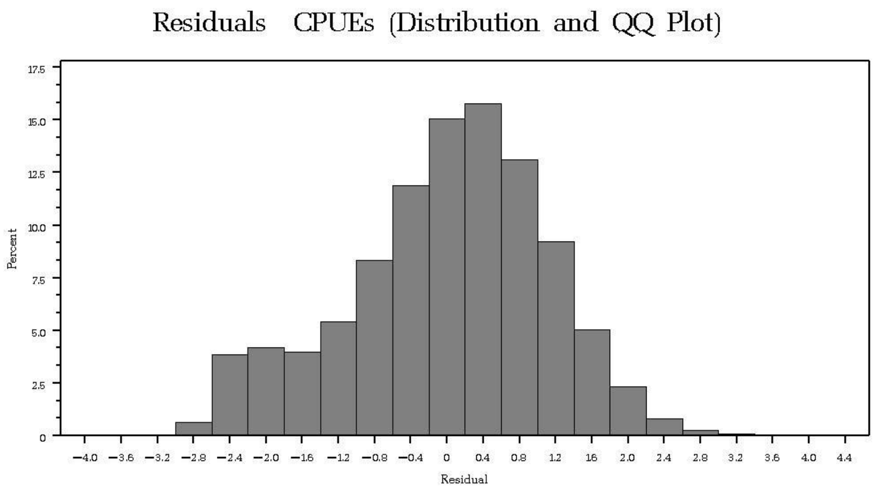

Figure 10. The residuals distribution of annual based CPUE standardization for the South Area from 1979 to 2009.

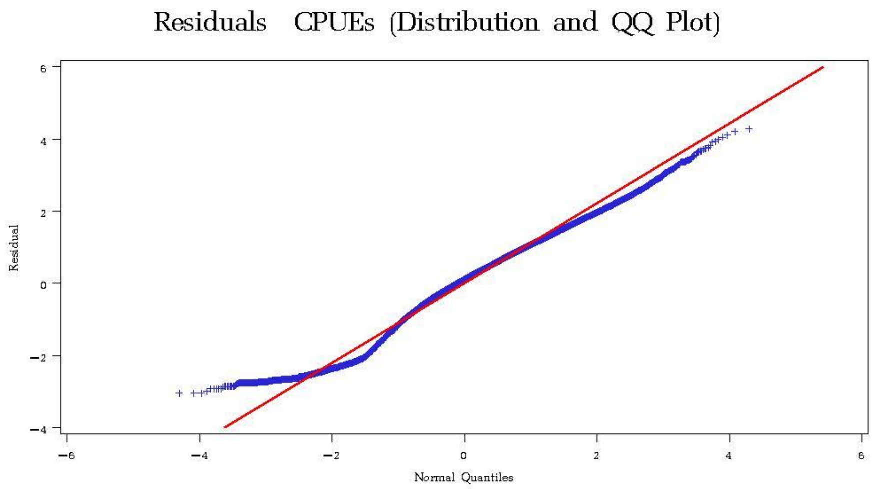

Figure 11. The QQPlot of annual based CPUE standardization for the South Area from 1979 to 2009.

4 References

Chang S-K, Liu H-I, Chang S-T (2008) CPUE standardizations for yellowfin yuna caught by taiwanese deep sea longline fishery in the tropical Indian Ocean using generalized linear model and generalized linear mixed model. Paper presented at the indian tuna commission working party on tropical tunas in 2008, Bangkok, Thailand.

Shu-Ting and Yu-Min Yeh (2009) Standardized Taiwanese CPUE for bigeye tuna in the Indian Ocean. IOT-C2009-WPTT-30.

Chien-Chung Hsu (2006) Standardized Catch per unit effort of bigeye tuna (Thunnus obesus) caught by Taiwanese longline fleets in the Indian ocean by genearl linear mixed model. IOTC-2006-WPTT-20.

Collette, B.B. and C.E. Nauen 1983 FAO Species Catalogue. Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of tunas, mackerels, bonitos and related species known to date. FAO Fish. Synop. 125(2). 137 p.

Devaraj M (1982) A critique on Indian Ocean fisheries development. 8(2):97-123.

Haward M, Bergin A (2000) Taiwan's distant water tuna fisheries. 24(1):33-43.

IOTC (2010) Report of the Twelfth Session of the IOTC Working Party on Tropical Tunas, in The T Session of the IOTC Working Party on Tropical Tunas, Victoria, Seychelles.

Yu-Min Yeh and Shu-Ting Chang. 2010. CPUE standardizations for Yellowfin tuna caught by Taiwanese lonlgine fishery in the Indian ocean using generalized liner model. IOTC-2010-WPTT-40.