SCIENTIFIC COMMITTEE
NINTH REGULAR SESSION

Pohnpei, Federated States of Micronesia
6-14 August 2013

Updated CPUE standardization for yellowfin tuna caught by Korean tuna longline fisheries in the Western and Central Pacific Ocean (1978-2012)

WCPFC-SC9-2013/SA-WP-12

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Abstract

In this study, yellowfin CPUE standardization of the Korean longline fisheries in the WCPO (1978-2012) was conducted using Generalized Linear Model (GLM) and operational data to assess the proxy of the abundance index. The data used for GLM were catch (number), effort (number of hooks) and number of hooks between floats (HBF) by year, month and area. Explanatory variables for the GLM analysis are year, quarter, area and NHF, and it was suggested that quarter effect was the largest factors affecting the nominal CPUE. The STD CPUE was about 15 in 1978, but since then it had sharply decreased until the early of 1990s, and showed a steady trend with a range of 2-3 in recent years.

1. Introduction

Yellowfin tuna has been the second highest catch species following bigeye tuna by Korean longline fisheries in the Western and Central Pacific Ocean (WCPO). Korean longline fisheries commenced in the late 1950s, but the catch data have been available since the mid-1980s. The catches were fluctuated between the lowest of 7,841 mt in 1991 and the peak of 15,497 mt in 2002 and stayed below the average (10,732 mt) in the recent years. It had shown slightly increasing trend prior to 2002 showing the highest catch amount, but since then it decreased until 2008, and is showing a stable level of about 8 thousands mt in the recent years (Fig. 1). In this study, yellowfin CPUE standardization of the Korean longline fisheries in the WCPO was brought up to data (1978-2012) using Generalized Linear Model (GLM) and operational data.

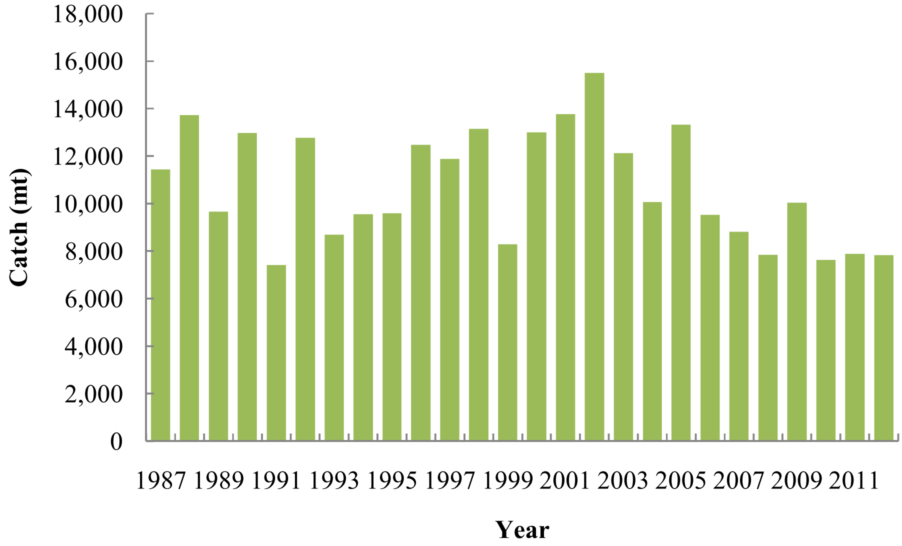

Fig. 1. Annual catch of yellowfin tuna caught by the Korean tuna longline fisheries in the WCPO.

2. Data and Methods

2.1 CPUE distribution

Fig. 2 shows distributions of average CPUE of yellowfin tuna caught by Korean longline fisheries by 5 years. Korean longline fisheries for targeting yellowing tuna have generally been operating in the tropical area of the WCPO between 20°N-20°S. However, for the 1980s, the latter half of 1990s and 2000s, they extended farther to the north and south to target species such as albacore tuna, etc. As shown in Fig. 2, it indicates that the density of CPUE for yellowfin tuna is higher in the tropical area, in particular between 150°E-170°W, than other area.

2.2 Area definition

Area definition for assessing yellowfin tuna in the WCPO is stratified into six regions (1-6) (Hoyle, 2010). But in this study, based on the fishing patterns of Korean longline fisheries, only two areas were used for yellowfin CPUE standardization, that is, area 1 (regions 1, 3 and 5) and area 2 (regions 2, 4 and 8) (Fig. 3). This is because there are a lot of missing data (no operations) in some regions (regions 1, 2, 5 and 6).

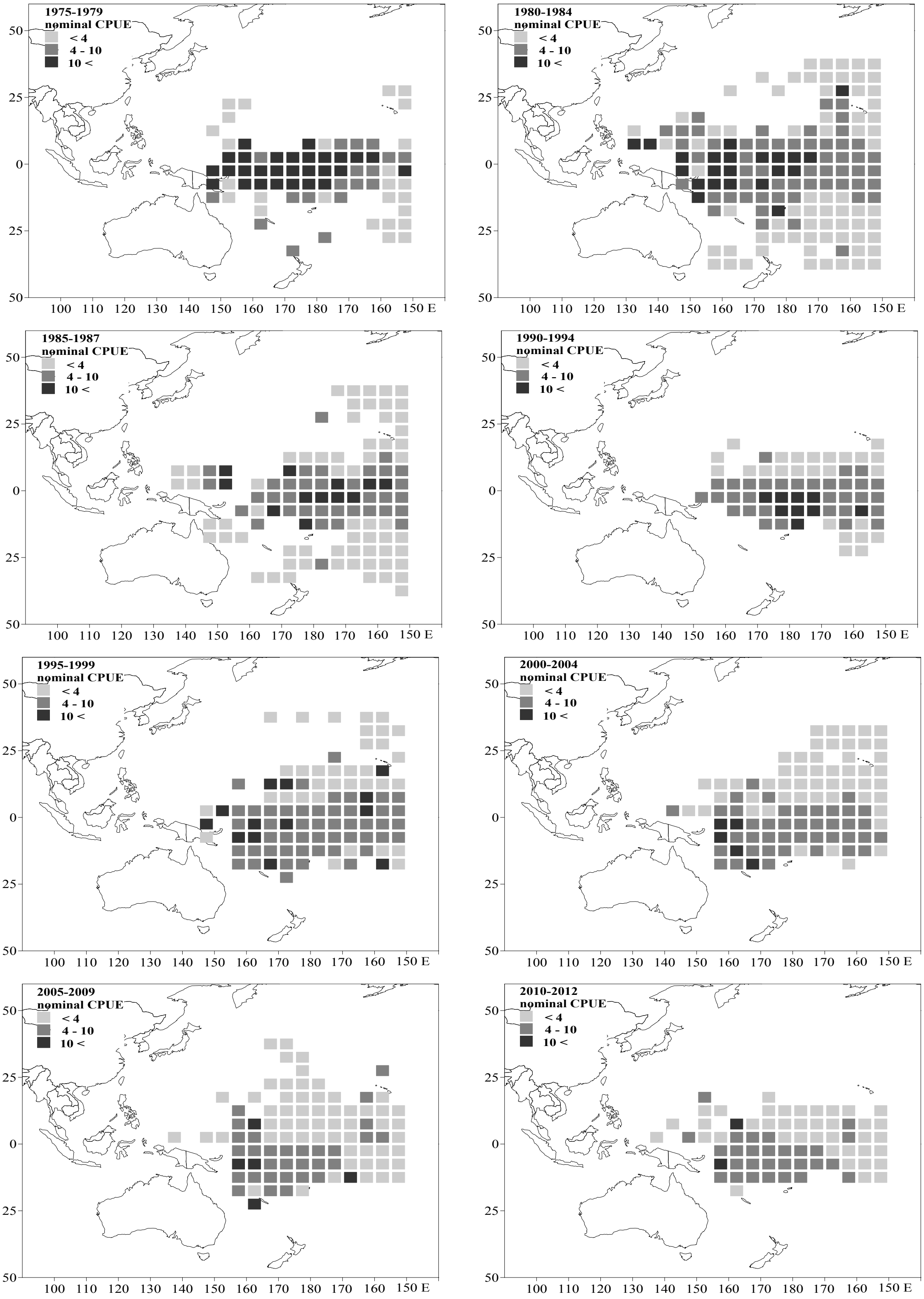

Fig. 2. Distributions of average CPUE (inds./1,000 hooks) of yellowfin tuna caught by Korean longline fisheries by 5 years.

2.3 Catch and effort data

Operational data for catch (number) and effort (number of hooks), NBF (number of hooks between floats) by year, month and area (1978-2012) were used for the yellowfin tuna CPUE standardization. The data before 1977 were not used in this study because they did not have data enough to carry out this analysis. Also the fishing information was not available in 1988-1989, hence the data in these two years were not included in this study.

The HBF was divided into 4 classes (class 1 : below 9, class 2 : 10-15, class 3 : 16-21, class 4 : above 22) based on the operating characteristics of the Korean tuna longline fisheries (Fig. 4). The main HBF used in fishing vessel was 6-7 in the 1970s and 1980s and 12-14 in the 1990s. Since 2000s it increased to 16-18, and HBF over 30 was used in some cases in recent years.

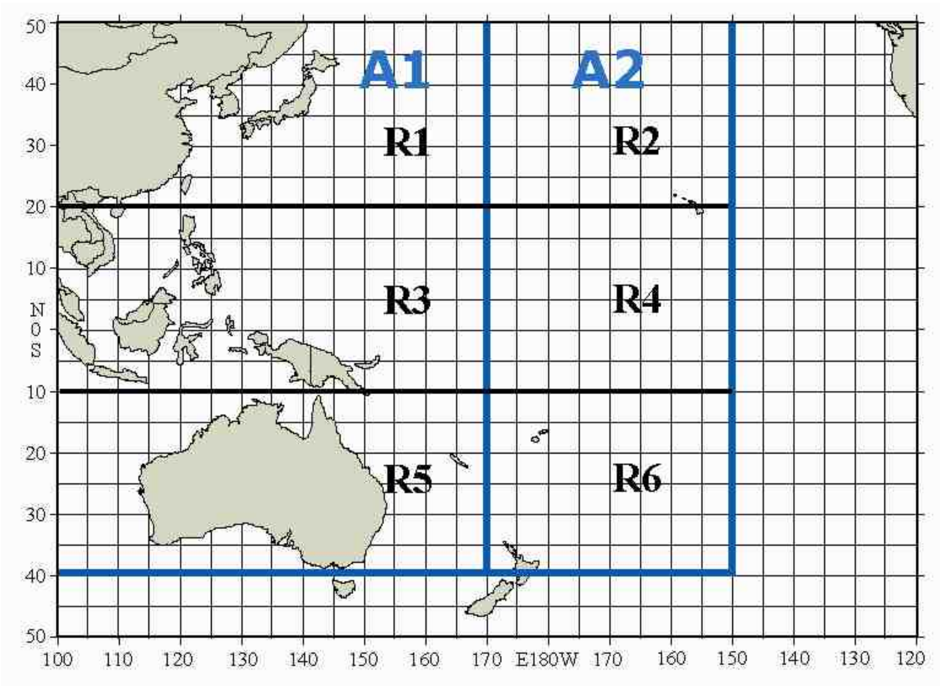

Fig. 3. Map showing two areas (Area 1=regions 1+3+5, and Area 2=regions 2+4+6) used for the yellowfin tuna CPUE standardization of the Korean longline fisheries in the WCPO.

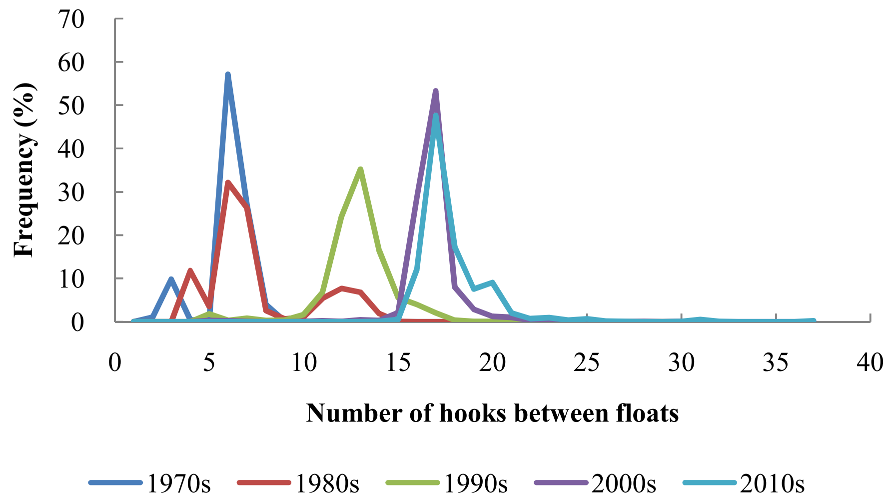

Fig. 4. Changes in the number of hooks between floats (HBF) used to the Korean tuna longline fisheries by decade.

2.4 Generalized Linear Model (GLM)

Generalized Linear Model (GLM) used for yellowfin tuna CPUE standardization is as follows, and we used SAS program (ver. 9.2) to obtain the results.

$$\mathrm{Ln}(\mathrm{CPUE} + c) = \mu + Y + Q + A + \mathrm{HBF} + Y\times A + Q\times A + Q\times \mathrm{HBF} + A\times \mathrm{HBF} + \mathrm{error}$$

where, CPUE : catch in number of yellowfin tuna per 1,000 hooks

c : 10% of average overall nominal CPUE

Y : effect of year

Q : effect of quarter (season)

A : effect of area (2 areas)

HBF : effect of targeting (4 classes)

Y×A : interaction term between year and area

Q×A : interaction term between quarter and area

Q×HBF : interaction term between quarter and HBF

A×HBF : interaction term between area and HBF

error : error term

3. Results and Discussion

Table 1 shows the ANOVA (type 3) for the GLM results which suggest that effects of all explanatory variables are significant, and quarter effect is the largest factor affecting the nominal CPUE.

Table 1. ANOVA table of GLM for yellowfin CPUE standardization

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	86	74276.974	863.6857	913.39	<.0001
Error	449618	425151.21	0.9456		
Corrected Total	449704	499428.18			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.148724	75.93461	0.972411	1.28059

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	32	5790.8721	180.96475	191.38	<.0001
QR	3	2001.9773	667.32578	705.73	<.0001
A	1	37.721312	37.721312	39.89	<.0001
G	3	397.36878	132.45626	140.08	<.0001
YR*A	32	2731.8085	85.369015	90.28	<.0001
QR*A	3	1292.9372	430.97906	455.78	<.0001
QR*G	9	1488.1322	165.34802	174.86	<.0001
A*G	3	101.89893	33.96631	35.92	<.0001

Figs. 5 and 6 show the standardized (STD) CPUE trends for yellowfin tuna with 95% confidence interval and with nominal CPUE, respectively. The STD CPUE was about 15 in 1978, but since then it had sharply decreased until the early of 1990s, and showed a steady trend with a range of 2-3 in recent years.

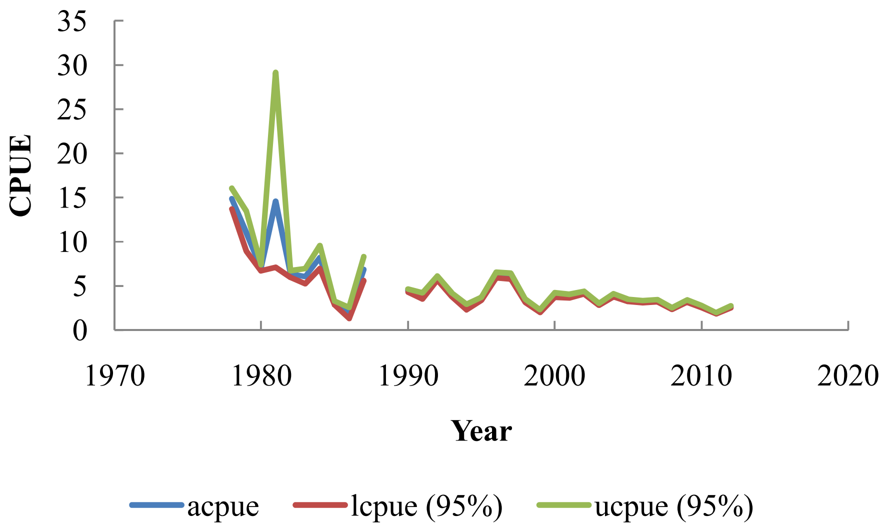

Fig. 5. Standardized (STD) CPUE with 95% confidence interval for yellowfin tuna of Korean tuna longline fisheries in the WCPO (1978-2012).

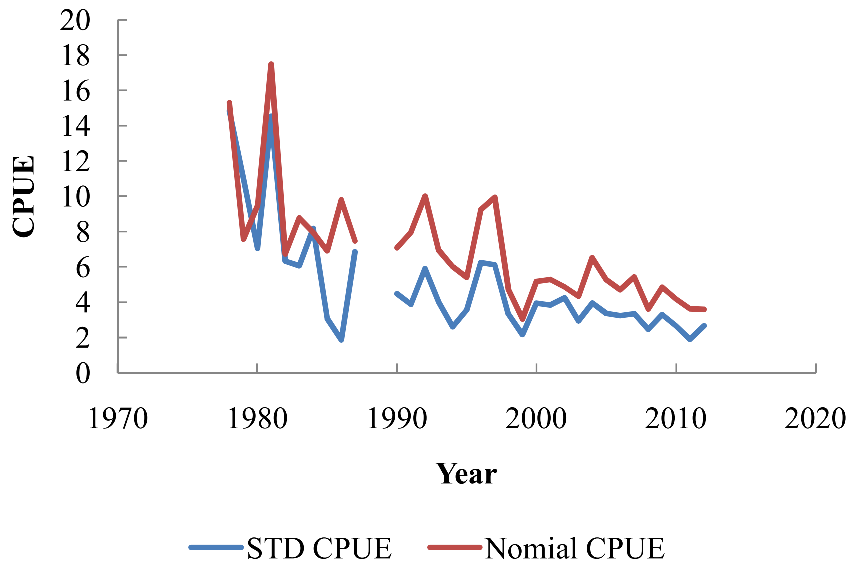

Fig. 6. Standardized (STD) and nominal CPUEs for yellowfin tuna of Korean longline fisheries in the WCPO (1978-2012).

Figs. 7-9 show the diagnostics for the GLM analyses that is percent frequency distribution, QQ-plots and box plot of the standardized residuals, respectively, and they suggested the data fit to the GLM fairly well.

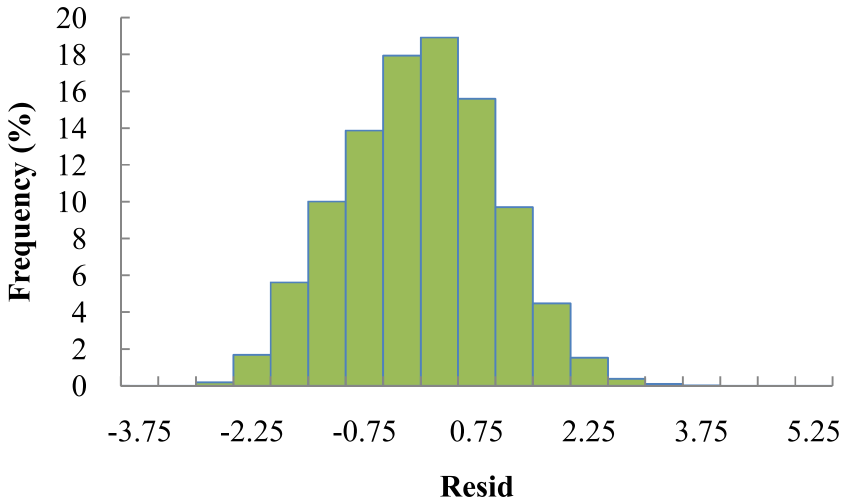

Fig. 7. Frequency distribution of the standardized residual for the GLM analysis.

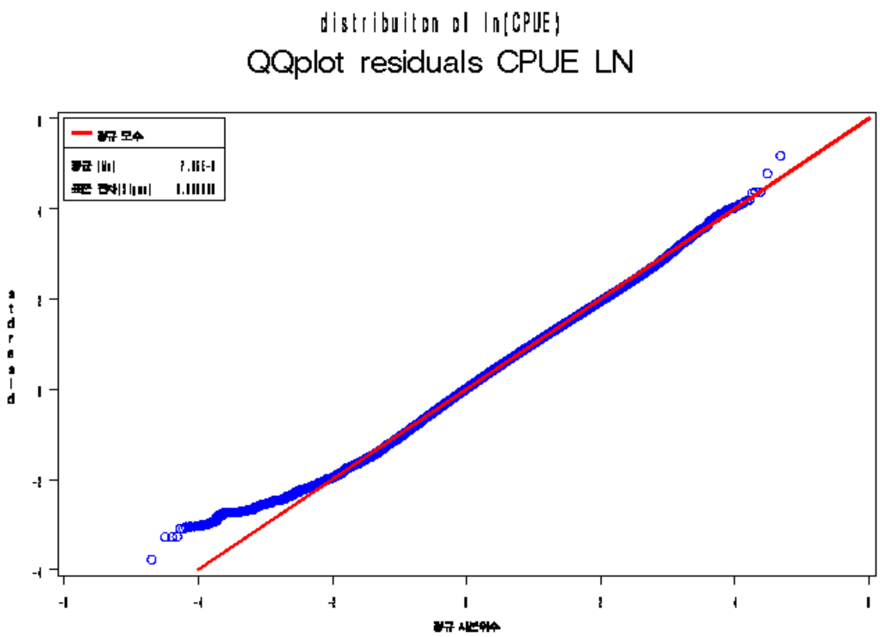

Fig. 8. QQ-plots of standardized residual for the GLM analysis.

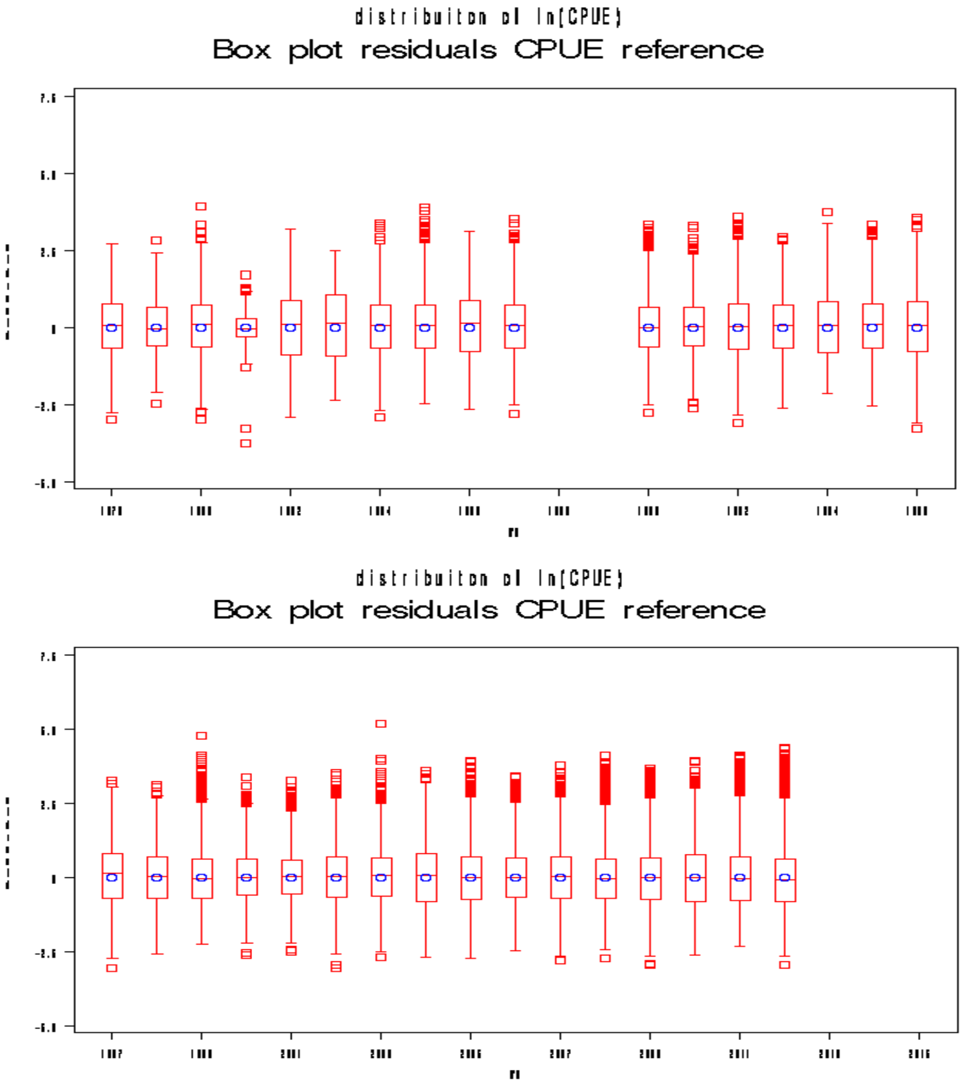

Fig. 9. Box plot of the stnadardized residual by year for the GLM analysis. Circle: mean, box: 25th and 75th percentile, horizontla line in the box: median, bars: maximum and minimum observation between 1.5 IQR (interqurtile range) above 75th percentile and 1.5 IQR below 25th percentile, squares: outliers.

References

Hoyle, S., 2010. CPUE standardization for bigeye and yellowfin tuna in the Western and Central Pacific Ocean. WCPFC-SC6-2010/SA-WP-03.