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CPUE standardization for bigeye tuna caught by Korean tuna longline fisheries in the Indian Ocean (1977-2012)

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Abstract

In this study, bigeye tuna CPUE (catch per unit effort) standardization of Korean longline fisheries in the Indian Ocean was conducted by Generalized Linear Model (GLM) using operational data and aggregated data (1977-2012) to assess the proxy of the abundance index. The data used for GLM were catch (in number), effort (number of hooks) and number of hooks between floats (HBF) by year, month and area. In addition, we explored the core area where Korean tuna longline vessels have been mainly fishing for bigeye tuna. Bigeye tuna CPUE was standardized for the whole area using both operational data and aggregated data and for the core area. All the CPUEs had decreased until the early of 2000s except a jump in the mid-1990s, and then showed a steady trend with a level of 2-3 in recent years.

Contents

1. Introduction

Bigeye tuna in the Indian Ocean has been a main species with one of the highest catch in Korean tuna longline fisheries along with yellowfin tuna. Bigeye tuna catch considerably increased from the mid-1960s and peaked at about 34 thousands mt in 1978, and then has decreased with a fluctuation. Since 2000, it is showing a level of about 1 thousand in average (Fig. 1). In this study, bigeye tuna CPUE (catch per unit effort) standardization of Korean tuna longline fisheries in the Indian Ocean (1977-2012) was conducted using Generalized Linear Model (GLM) to assess the proxy of the abundance index.

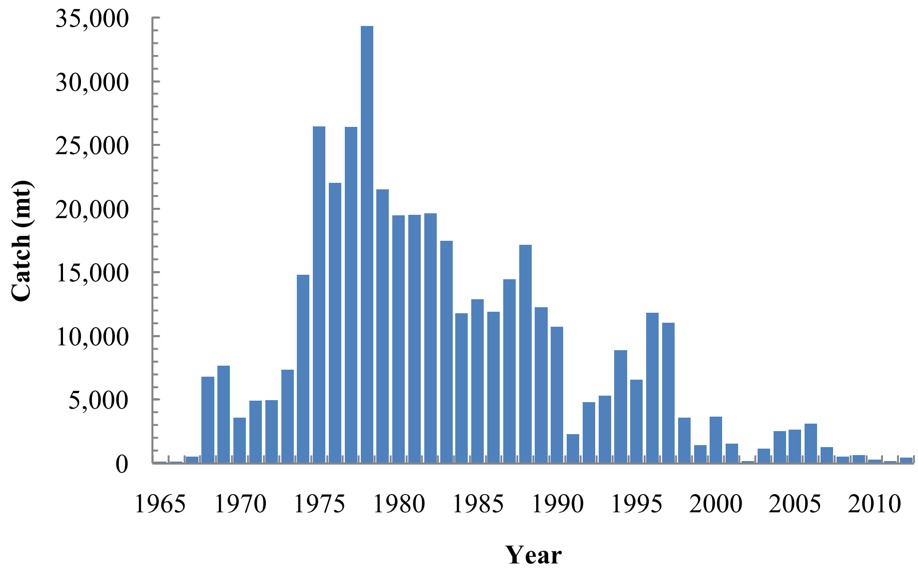


Fig.1. Annual catch of bigeye tuna caught by Korean tuna longline fisheries in the Indian Ocean (data source: IOTC database).

2. Data and Methods

2.1. Data

In this study, aggregated and operational data on Korean tuan longline fisheries were used for the bigeye tuna CPUE standardization, which contained catch (number of fishes) and effort (number of hooks), HBF (number of hooks between floats) by year, month and area from 1977 to 2012. The data prior to 1976 were not used because there were many missing information in the dataset to conduct GLM.

2.2. Definition of area and season

Based on the fishing patterns of Korean tuna longline fisheries, only 2 areas (modified from Okamoto and Shono, 2006), that is, East (area 1, 3 and 6) and West (areas 2, 4, 5, 6 and 7) were used for standardizing bigeye tuna CPUE of Korean tuna longline fisheries (Fig. 2). Another significant reason to combine into 2 large areas is that when we use each sub area, it is likely to have a lot of missing values (no operations) in some sub areas in some seasons, which make it difficult to run GLM. And area 67 was not used in this study.

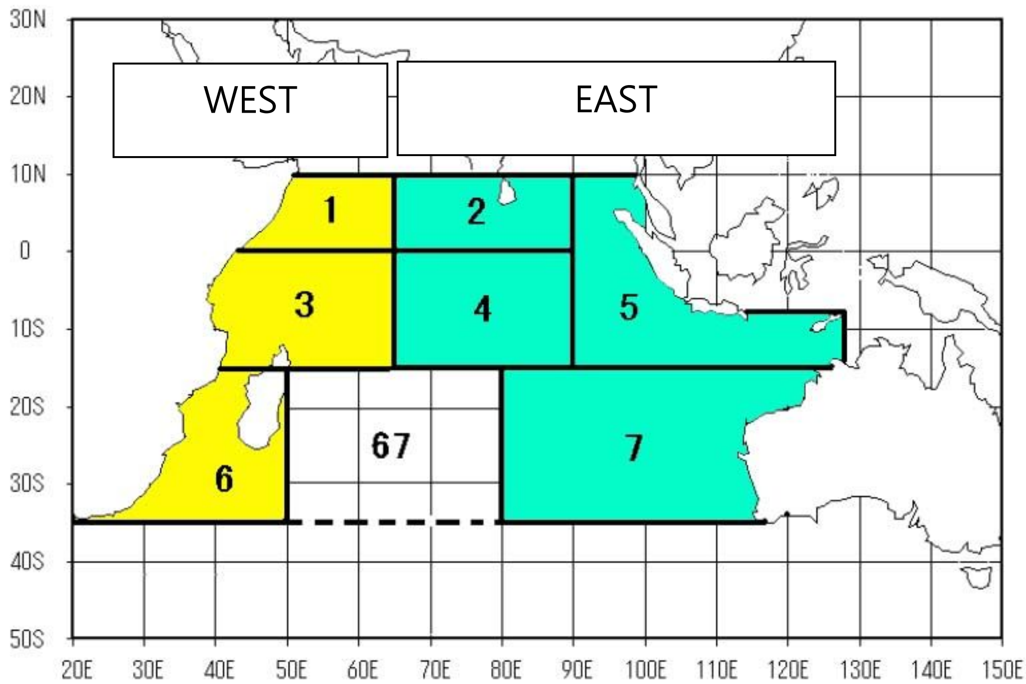


Fig. 2. Map showing areas used for the bigeye tuna CPUE standardization of Korean tuna longline fisheries in the Indian Ocean (modified from Okamoto and Shono, 2006). (West=1+3+6, East=2+4+5+7).

Furthermore, monthly data were combined into 2 seasons (by a half year) likewise the combination of areas was combined into 2 large areas for bigeye tuna CPUE standardization of Korean tuna longline fisheries.

2.3. Changes in number of hooks between floats (HBF)

Fig. 3 shows the annual changes in the number of hooks between float (HBF) used in Korean tuna longline fisheries. The main HBF was below 9 hooks (regular) from the 1970s to the mid-1980s, and 10-14 hooks (deep) were mainly used from the mid-1980s to the mid-1990s. Since then it was increased more than 15 (ultra deep) and used until the mid-2000s, and 10-14 hooks (deep) were often used in recent years. The HBF was divided into 5 classes (class 1 : below 8, class 2 : 9-11, class 3 : 12-14, class 4 : 15-17, class 5 : above 18) based on the fishing operational pattern of Korean tuna longline fisheries.

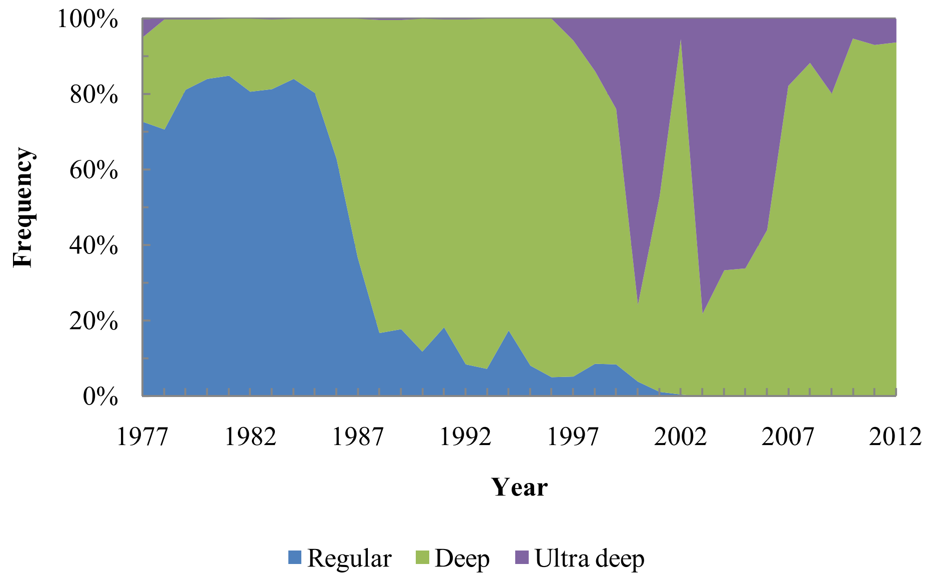


Fig. 3. Annual changes in the number of hooks between float (HBF) used in Korean tuna longline fisheries in the Indian Ocean.

2.4. Core area of bigeye tuna

To explore the core area where vessels have mainly operated to fish for bigeye tuna, we analyzed the frequency of fishing year when there was 1 bigeye tuna or more caught by area.

In this study, the core area was defined as the area where fishing for bigeye tuna had occurred more than 20 times in the same area during 1977-2012.

2.5. Generalized Linear Model (GLM)

Bigeye tuna CPUE was standardized for the whole area and the core area using aggregated data and operational data, and Generalized Linear Model (GLM) used in this study are as follows. The analyses were conducted by SAS program (ver. 9.2).

- **Whole area** : $\ln(CPUE + c) = \mu + Y + S + A + HBF + Y{\times}A + S{\times}A + S{\times}HBF + A{\times}HBF + S{\times}A{\times}HBF + error$

- **Core area** : $\ln(CPUE + c) = \mu + Y + S + HBF + S{\times}HBF + error$

where, CPUE : catch in number of bigeye tuna per 1,000 hooks
c : 10% of average overall nominal CPUE
Y : effect of year
S : effect of season (2 seasons)
A : effect of area (Areas 1 and 2)
HBF : effect of targeting (5 classes)
Y×A : interaction term between year and area
S×A : interaction term between season and area
S×HBF : interaction term between season and HBF
A×HBF : interaction term between area and HBF
S×A×HBF : interaction term among season, area and HBF
error : error term

3. Results and Discussion

3.1. Core area

Fig. 4 shows the frequency of fishing year by quarter of Korean tuna longline vessels fishing for bigeye tuna during 1977-2012. The core area of Korean tuna longline fisheries was formed at 5°N-15°S between40°E-90°E (mainly areas 3 and 4). In the 1st and 2nd quarters, the core was mainly formed at areas 1 and 3, and extended to areas 2 and 4 in the 3rd and 4th quarters.

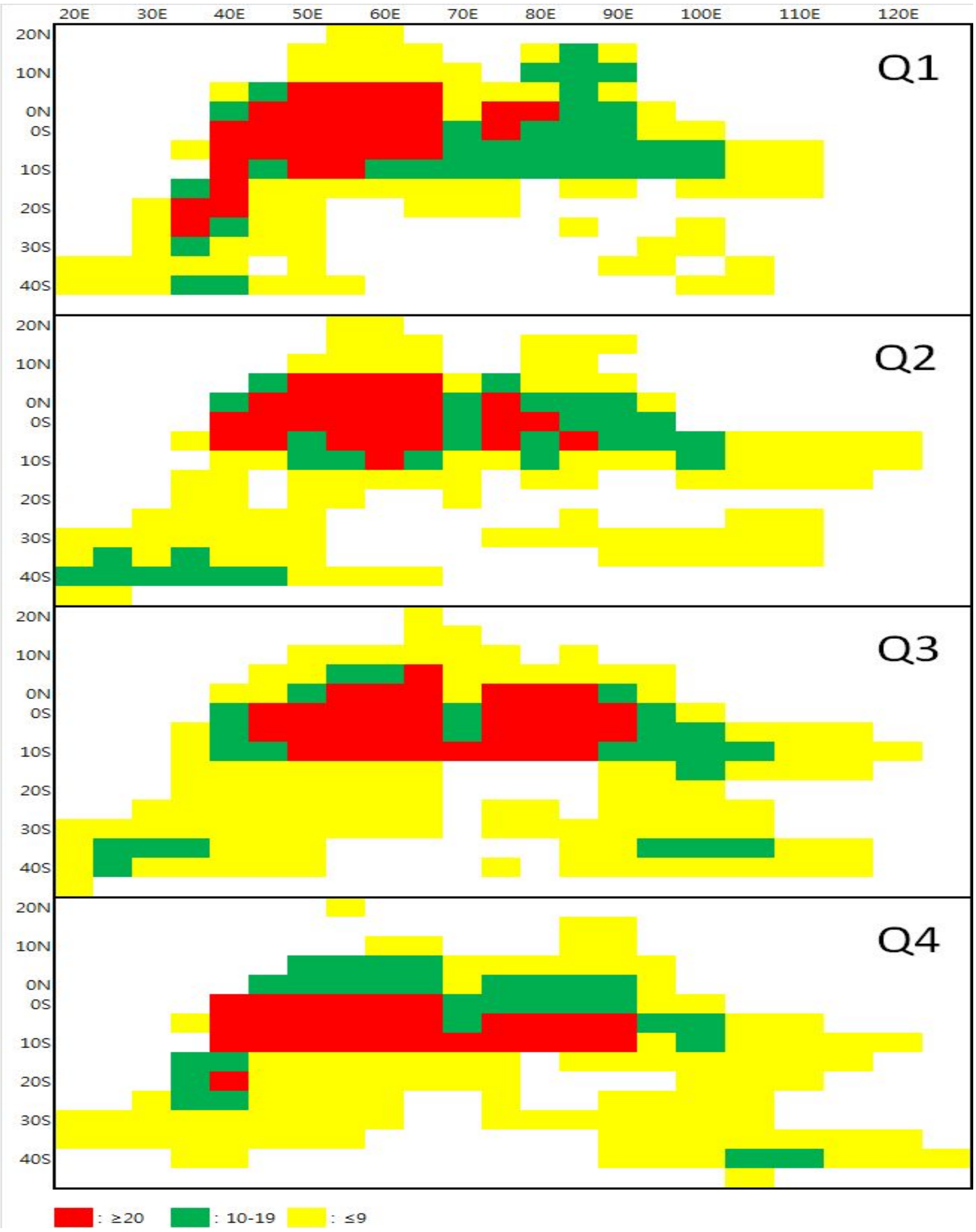


Fig. 4. Map showing the core area of Korean tuna longline vessels for fishing bigeye tuna in the Indian Ocean, 1977-2012.

3.2. Standardized CPUEs

Fig. 5 shows the standardized (STD) CPUE trends of bigeye tuna for the whole area using operational data with nominal CPUE in real and relative scales. The standardized CPUE was about 10 in 1977, but since then it had shown the declining trend until the early of 2000s except one jump in 1996, and showed a steady trend with a level of 2-3 in recent years. Both the standardized and nominal CPUEs showed a similar trend, but they had differences from the end of 1990s to the mid-2000s.

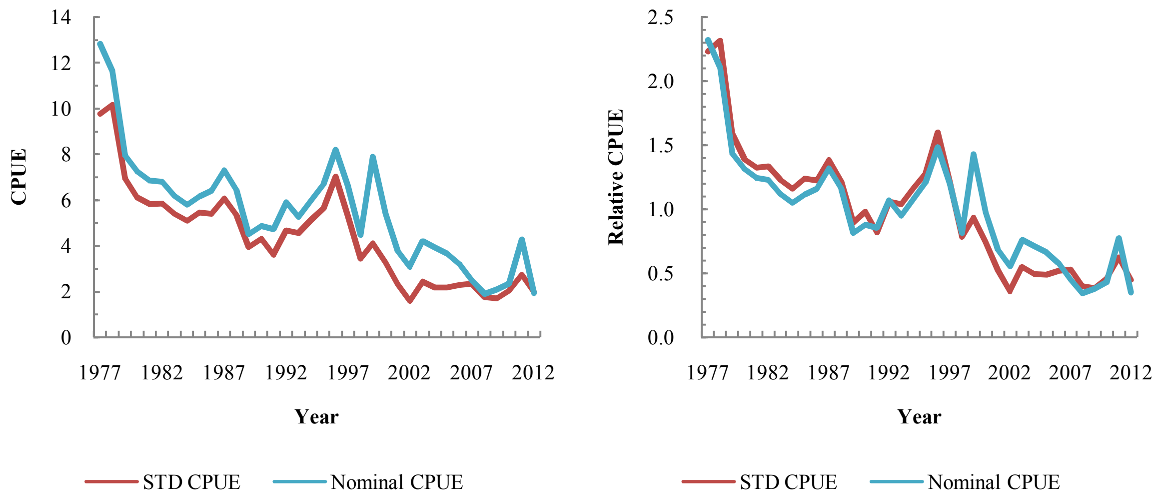


Fig. 5. Standardized (STD) and nominal CPUEs of bigeye tuna for the whole area of Korean tuna longline fisheries in the Indian Ocean using operational data (1977-2012).

Fig. 6 shows the standardized (STD) CPUE trends of bigeye tuna for the whole area using aggregated data with nominal CPUE in real and relative scales. The standardized CPUE also had differences with the nominal CPUE from the end of 1990s to the mid-2000s.

The standardized and nominal CPUE trends for the core area Korean tuna longline vessels fishing for bigeye tuna is shown in Fig. 7.

As shown in Figs. 5. 6 and 7, the standardized CPUE for the whole area using operational data and the core area had more difference with the nominal CPUE in real scale than those of using aggregated data.

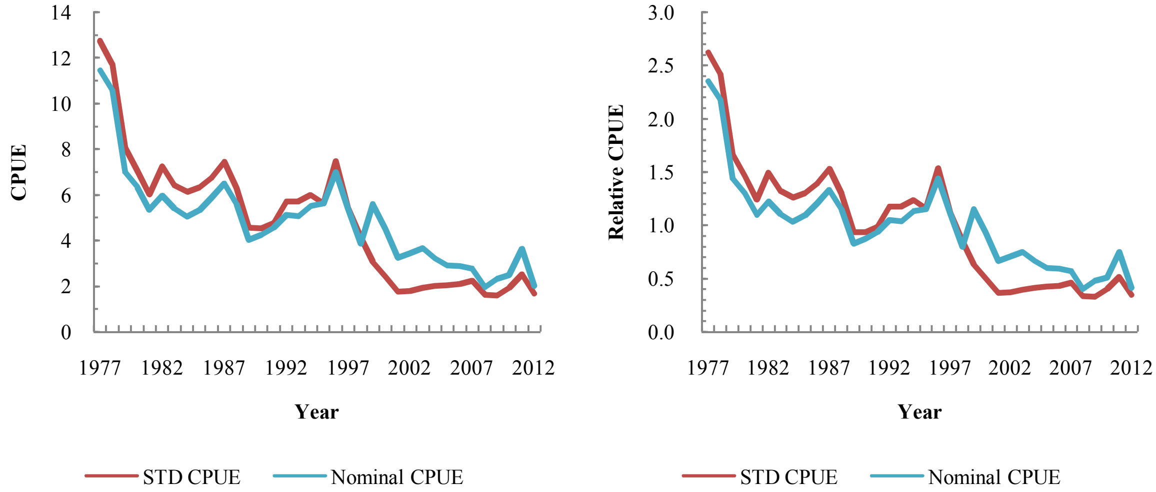


Fig. 6. Standardized (STD) and nominal CPUEs of bigeye tuna for the whole area of Korean tuna longline fisheries in the Indian Ocean using aggregated data (1977-2012).

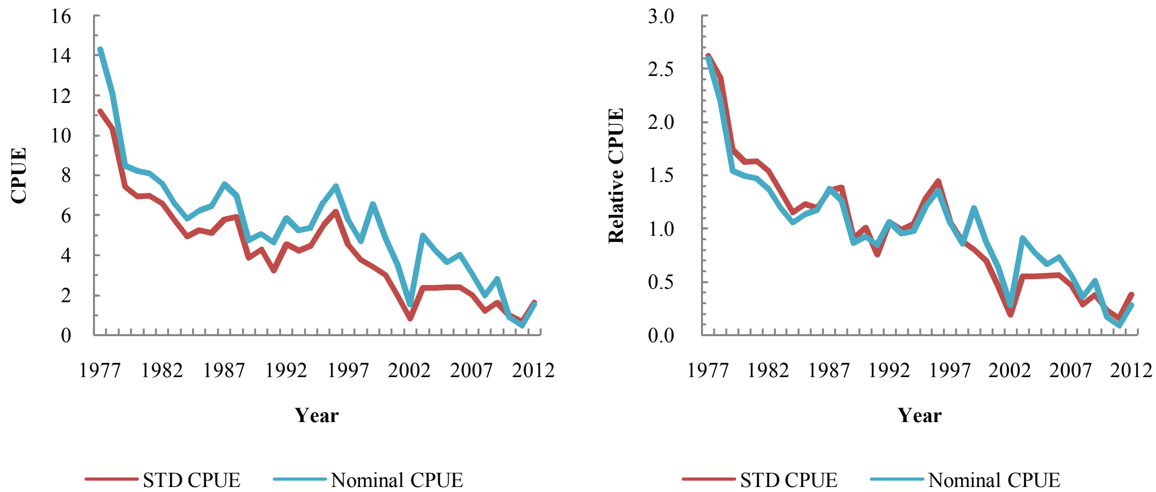


Fig. 7. Standardized (STD) and nominal CPUEs of bigeye tuna for the core area of Korean tuna longline fisheries in the Indian Ocean using operational data (1977-2012).

The ANOVA (type 3) results from the GLMs are shown in Table 1, and it suggests that area effect is the largest factor affecting the nominal CPUE in the whole area model with area effect, and year effect is the largest factor in the core area model without area effect.

Figs. 8, 9 and 10 show frequency distribution, Q-Q plots and box plots of the standardized residuals, respectively.

Table 1. ANOVA results of the GLM for bigeye tuna CPUE standardization

(a) Whole area using operational data

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	89	30337.754	340.8736	458.83	<.0001
Error	288719	214493.64	0.7429		
Corrected Total	288808	244831.4			

R-Square	CoeffVar	Root MSE	lncpue Mean
0.123913	53.79132	0.861925	1.60235

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	35	12278.012	350.80035	472.19	<.0001
S	1	86.17922	86.17922	116	<.0001
A	1	493.39484	493.39484	**664.13**	<.0001
G	4	557.39279	139.3482	187.57	<.0001
YR*A	35	1102.5294	31.50084	42.4	<.0001
S*A	1	45.4108	45.4108	61.13	<.0001
S*G	4	99.81185	24.95296	33.59	<.0001
A*G	4	149.66392	37.41598	50.36	<.0001
S*A*G	4	152.32238	38.0806	51.26	<.0001

(b) Whole area using aggregated data

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	89	1564.3713	17.577205	41.43	<.0001
Error	10051	4264.0104	0.424237		
Corrected Total	10140	5828.3817			

R-Square	CoeffVar	Root MSE	lncpue Mean
0.268406	41.37123	0.651335	1.574367

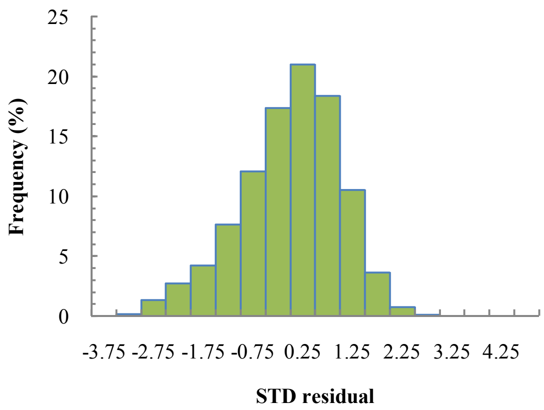
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	35	753.13319	21.518091	50.72	<.0001
S	1	5.0475057	5.0475057	11.9	0.0006
A	1	28.696005	28.696005	**67.64**	<.0001
G	4	97.999691	24.499923	57.75	<.0001
YR*A	35	82.703393	2.3629541	5.57	<.0001
S*A	1	0.3397136	0.3397136	0.8	0.3709
S*G	4	2.7767979	0.6941995	1.64	0.162
A*G	4	10.60082	2.650205	6.25	<.0001
S*A*G	4	8.6793344	2.1698336	5.11	0.0004

(c) Core area

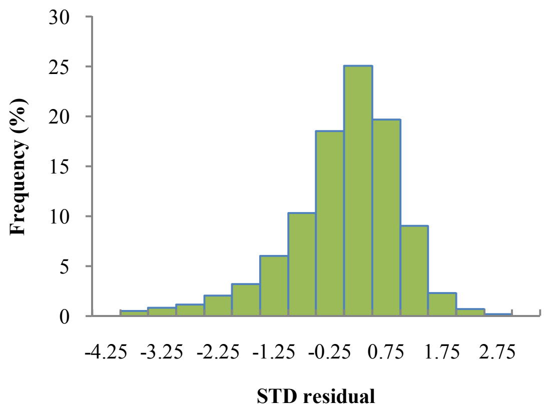
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	44	7957.1926	180.84529	243.87	<.0001
Error	105461	78207.672	0.74158		
Corrected Total	105505	86164.864			

R-Square	CoeffVar	Root MSE	lncpue Mean
0.092348	53.50432	0.86115	1.609496

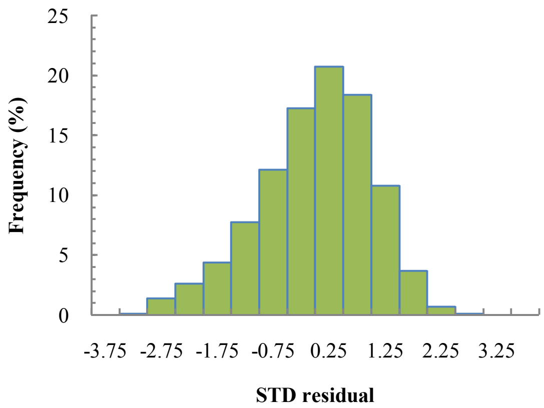
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	35	5511.3381	157.4668	**212.34**	<.0001
S	1	74.895255	74.895255	100.99	<.0001
G	4	206.043	51.510751	69.46	<.0001
S*G	4	181.89545	45.473862	61.32	<.0001



(a) Whole area using operational data

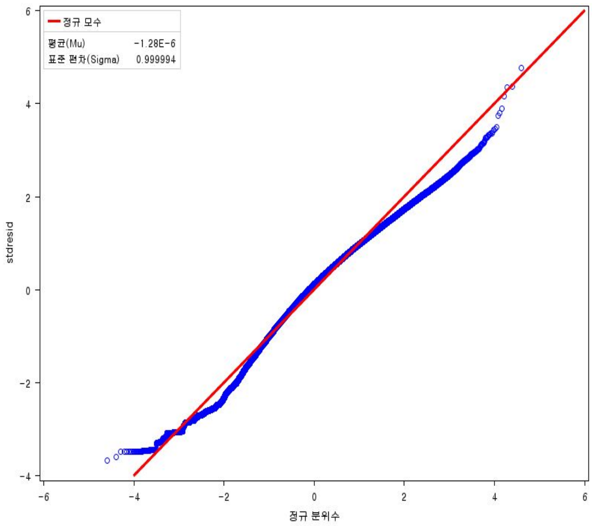


(b) Whole area using aggregated data

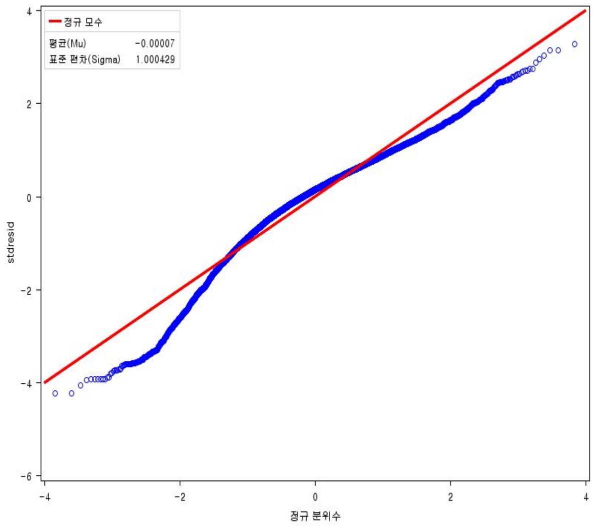


(c) Core area

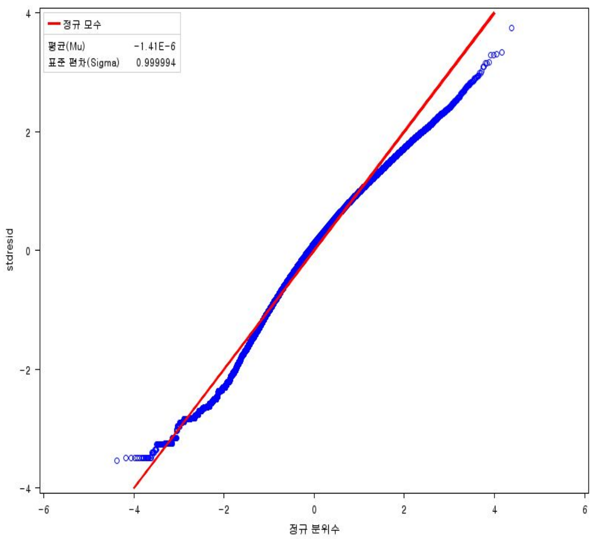
Fig. 8. Distribution of the standardized residual for the GLM analyses.



(a) Whole area using operational data

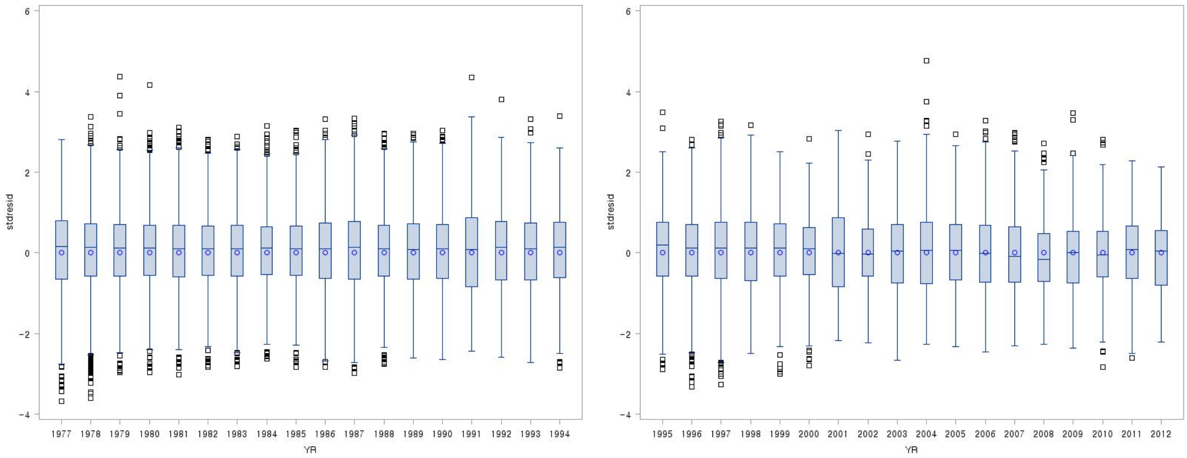


(b) Whole area using aggregated data

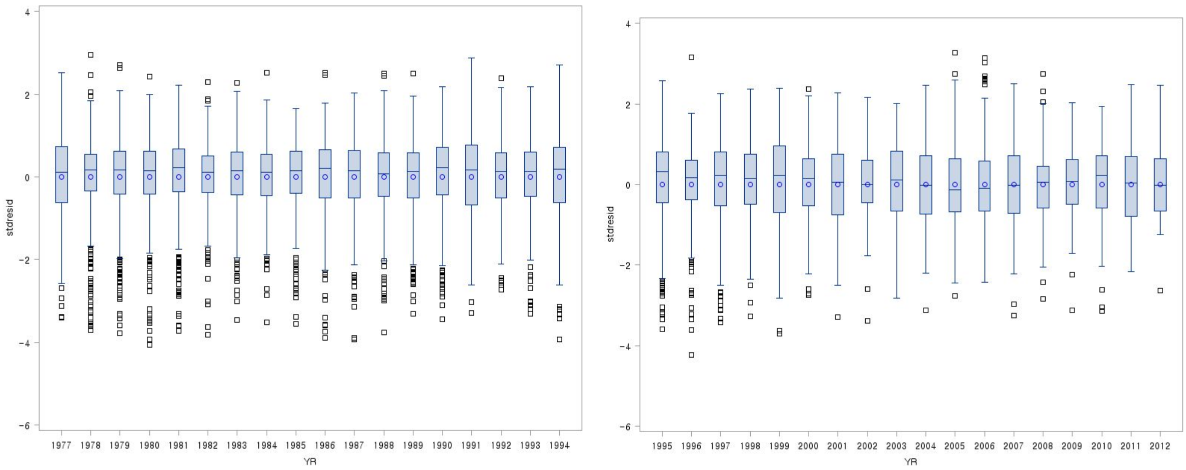


(c) Core area

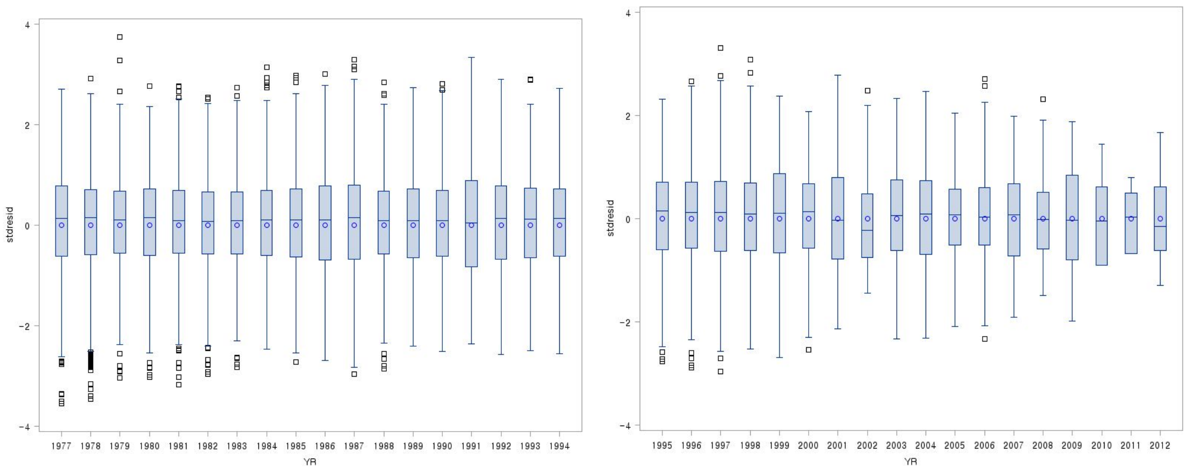
Fig. 9. QQ-plots of the standardized residual for the GLM analyses.



(a) Whole area using operational data



(b) Whole area using aggregated data



(c) Core area

Fig. 10. Box plot of the standardized residual by year for the GLM analyses. Circle: mean, box: 25th and 75th percentile, horizontal line in the box: median, bars: maximum and minimum observation between 1.5 IQR (inter quartile range) above 75th percentile and 1.5 IQR below 25th percentile, squares: outliers.

3.3. Comparison of CPUEs

Fig. 11 shows comparisons of standardized CPUEs among the whole area using operational data (OP) and aggregated data (AG) and the core area (CA). All the CPUEs had decreased until the early of 2000s except a jump in the mid-1990s, and then showed a steady trend with a level of 2-3 in recent years. The standardized CPUE from the mid-1980s to the mid-1990s for the whole area using operational data and the core area had a difference from those of using aggregated data in real scale, and those of core area showed a decreasing in 2010 and 2011unlike those of the whole area.

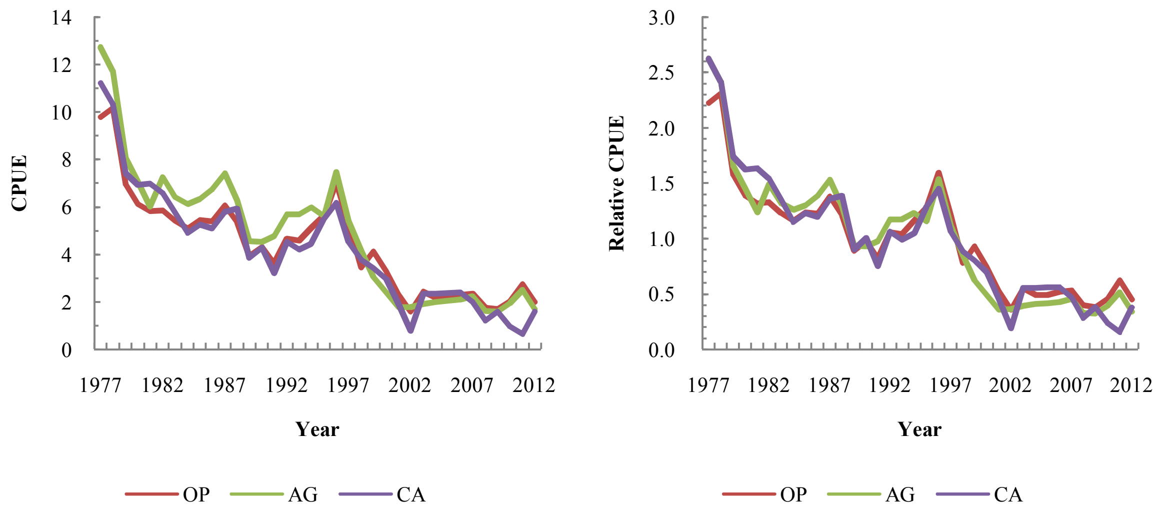


Fig. 11. Comparison of the standardized CPUEs of bigeye tuna for the whole area using operational data and aggregated data and the core area of Korean tuna longline fisheries, 1977-2012.

References

Okamoto, H. and H. Shono, 2006. Japanese longline CPUE for bigeye tuna in the Indian Ocean up to 2004 standardized by GLM applying gear material information in the model. IOTC-2006-WPTT-1, pp. 17.