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CPUE standardization of albacore tuna caught by Korean tuna longline fishery in the Indian Ocean

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Abstract

In this study, CPUE (catch per unit effort) standardization for albacore tuna of Korean longline fishery in the Indian Ocean was conducted by Generalized Linear Model (GLM) using operational (set by set) data 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. Albacore tuna CPUE by Korean tuna longline fishery was standardized for the whole area and for the core area. The standardized CPUE had had a stable trend at low level until 2006 and all of CPUEs started to increase in 2007, since then, however, those show different trends among each model.

Introduction

Albacore tuna has been one of major important commercial species of Korean tuna longline fishery in the Indian Ocean. Albacore tuna catch had considerably increased from the mid-1960s and peaked at about 10 thousand mt in 1974, but sharply decreased to below a hundred tons thereafter. Since 2009 it has started to increase in the mid-2000s, which showed about 5 hundred mt in 2013 (Fig. 1). In this study, CPUE standardization of albacore tuna caught by Korean tuna longline fishery in the Indian Ocean was conducted using Generalized Linear Model (GLM) to assess the proxy of the abundance index.

Data and Methods

In this study, operational (set by set) data of Korean tuna longline fishery were used for albacore tuna CPUE standardization, which complied from captain onboard and contained catch (number of fishes), effort (number of hooks) and HBF (number of hooks between floats) by year, month and area from 1977 to 2013. The data prior to 1976 were not used because there were many missing information in the dataset to conduct GLM.

Based on the fishing patterns of Korean tuna longline fishery and biology on albacore tuna, area was classified into 2 large areas (modified from Matsumoto and Uosaki, 2011) for standardizing albacore tuna CPUE for the whole area of Korean tuna longline fishery (Fig. 2). Another significant reason to reduce to 2 large areas is that when sub areas classified in Matsumoto and Uosaki (2011) are used, there are a lot of missing values (no operations) in some sub areas in some seasons, which make it difficult to run GLM.

The HBF was divided into 3 classes (class 1: below 9 hooks, class 2: 10-14 hooks, class 3: above 15 hooks) based on the operational patterns of Korean tuna longline fisheries (Lee et al., 2014).

In addition, albacore tuna CPUE standardization for the core area was conducted as considering followed two ways. Firstly, to explore the core area where vessels have mainly operated to fish for albacore tuna, we analyzed the frequency of fishing year when there was 1 SBT or more caught in each $5^{o}\times5^{o}$ area. In this study, the core area was defined as the area where fishing for albacore tuna had occurred more than 15 times in the same area during 1977-2013 (case 1). Secondly, the area of 0^{o}-15^{o}S between 40^{o}E-100^{o}E (Fig. 3) was chosen as the core area based on the operational patterns of Korean tuna longline fishery and its area where vessels have mainly operated to fish for albacore tuna (case 2).

Generalized Linear Model (GLM) for albacore tuna CPUE standardization for both the whole area and the core area are as follows, and the analyses were conducted by SAS program (ver. 9.2).

Whole area: $\text{Ln}(CPUE + c) = \mu + Y + Q + A + G + Q\times A + A\times G + Q\times G + error$

Core area: $\text{Ln}(CPUE + c) = \mu + Y + Q + G + Q\times G + error$

where, CPUE: catch in number of albacore tuna per 1,000 hooks
c: 10% of average overall nominal CPUE
Y: effect of year
Q: effect of quarter
A: effect of area (2 areas)
G: effect of gear (3 classes)
Q×A: interaction term between quarter and area
A×G: interaction term between area and gear
Q×G : interaction term between quarter and gear
error: error term

Results and Discussion

Fig. 4 shows the frequency of fishing year by quarter for Korean tuna longline vessels fishing for albacore tuna during 1977-2013. In the 1st and 2nd quarters, the core area was mainly formed at 0°-15°S between 45°E-70°E, and in the 1st quarter it was formed at area of 15°S-25°S between 35°E -45°E, in particular. In the 3rd quarter, the core area was extended from 50°E to 105°E around 0°-15°S, and moved westward from 40°E to 95°E in the 4th quarter, which were larger in the area size than those in the 1st and 2nd quarters.

Fig. 5 shows the standardized CPUE trends of albacore tuna for the whole area with confidence interval in real scale and with nominal CPUE in relative scale. The standardized CPUE was about 0.2 in 1977 and showed the stable trend at low level until 2006. Since 2007 it has increased, which showed the highest level of 1.2 in 2013 (Table 2). Both the standardized and nominal CPUEs showed a similar trend in relative scale except for those of 1978, 2010-2013 when showed a large increasing in nominal CPUE. The standardized CPUE for the core area where vessels have mainly operated to fish for albacore tuna (case 1) is shown in Fig. 6. The standardized CPUE had a difference with that of the whole area in recent years. It has increased since 2007 in the whole area, whereas it decreased sharply after

2012 in the core area. Fig. 7 shows the standardized CPUE trends of albacore tuna for the core area defined as area of 0^o-15^oS between 40^oE-100^oE (case 2). It showed an increasing trend from 1977 to 1986, since then it had decreased until the late 1980s. From the early 1990s to mid 2000s, it showed a steady trend with fluctuations. It sharply increased in 2007 when recorded the highest, decreased again in 2008, and then has shown an increasing trend in recent years.

The ANOVA (type 3) results for the GLMs are shown in Table 1. As for the whole area model, it suggests that area effect is the largest factor affecting the nominal CPUE. As for the core area models, gear and year effects are the largest factors in case 1 and 2, respectively.

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

Fig. 11 shows comparisons of standardized CPUEs among the whole area model and the core area model. All of CPUEs started to increase in 2007, since then, however, those show different trends among each model.

References

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Matsumoto, T. and K. Uosaki, 2011. Standardization of albacore CPUE by Japanese longline fishery in the Indian Ocean. IOTC–2011–WPTmT03–15, 1-10.

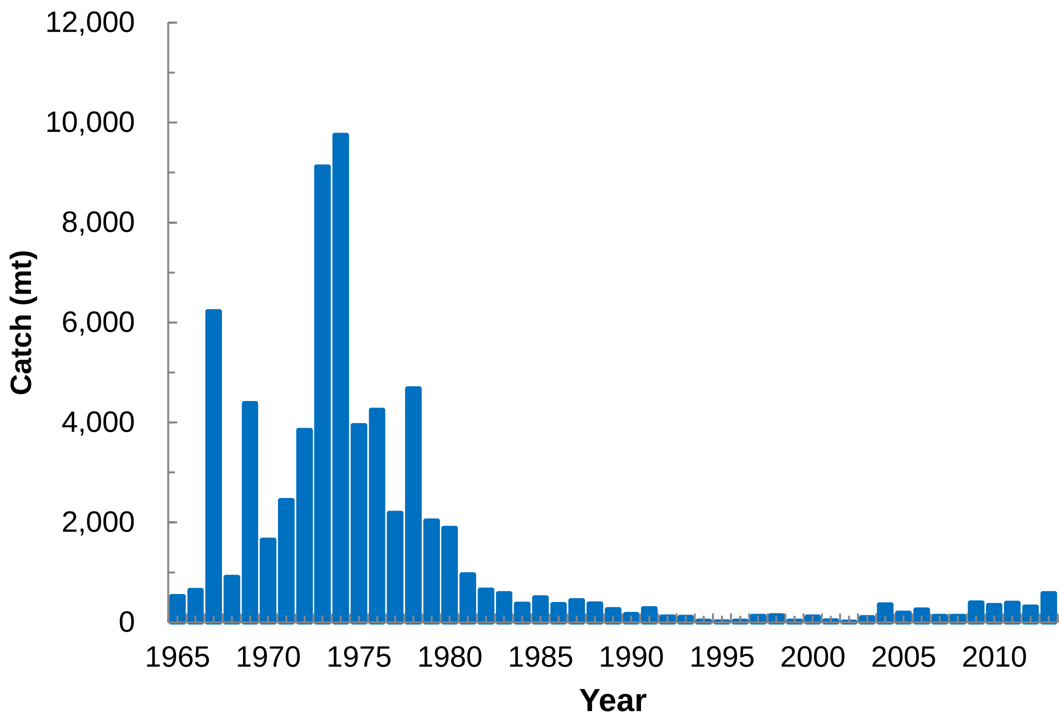


Fig. 1. Annual catch of albacore tuna caught by Korean tuna longline fishery in the Indian Ocean, 1965-2013 (Data source: IOTC database).

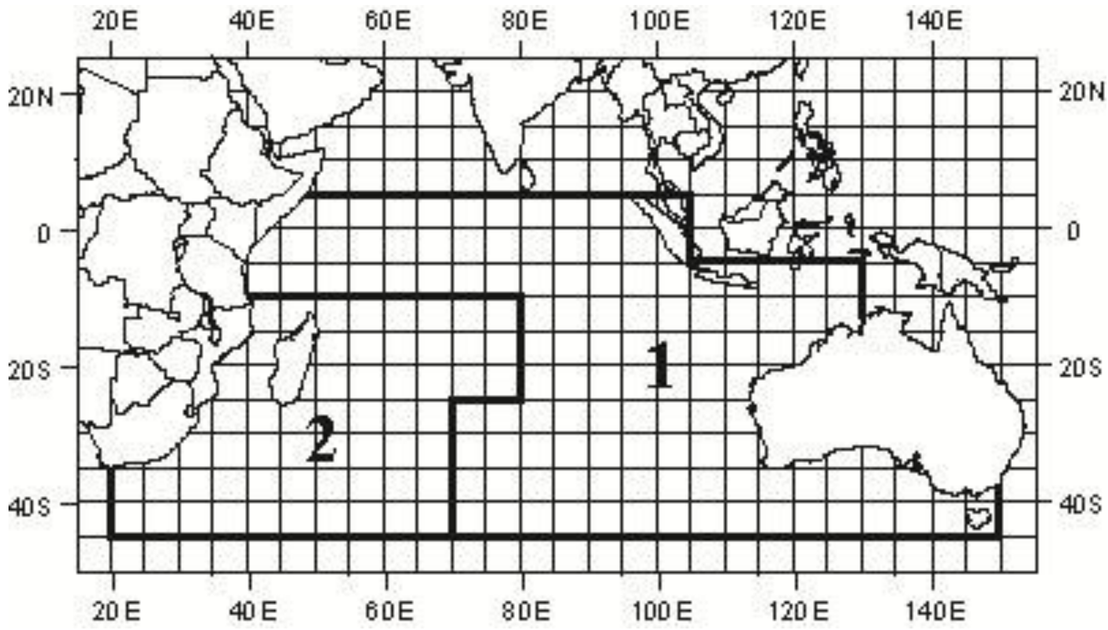


Fig. 2. Map showing areas used for albacore tuna CPUE standardization of Korean tuna longline fishery in the Indian Ocean (modified from Matsumoto and Uosaki, 2011).

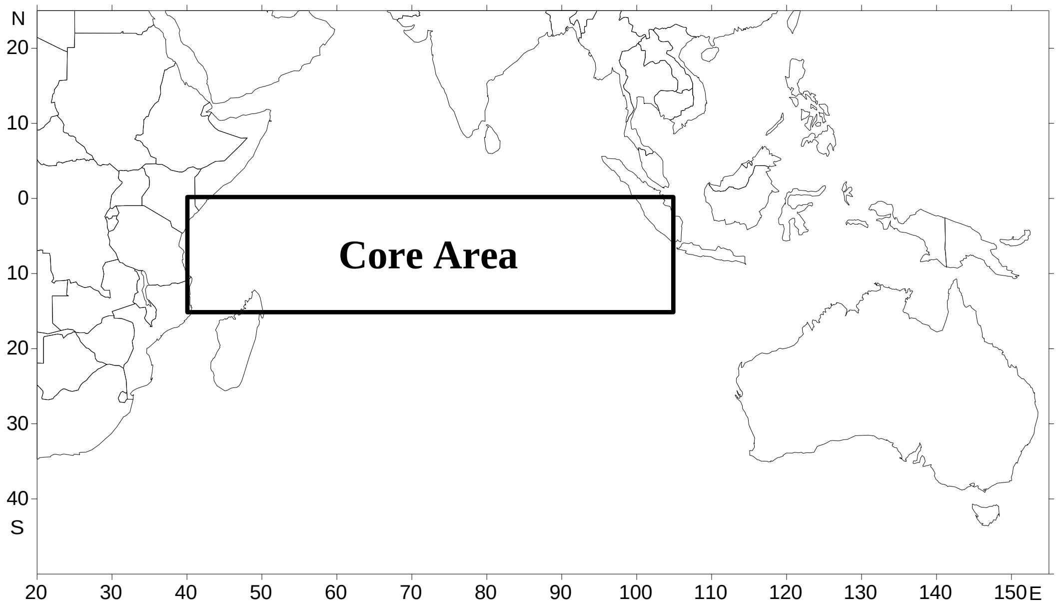


Fig. 3. Core area of Korean tuna longline fishery used for the GLM analysis.

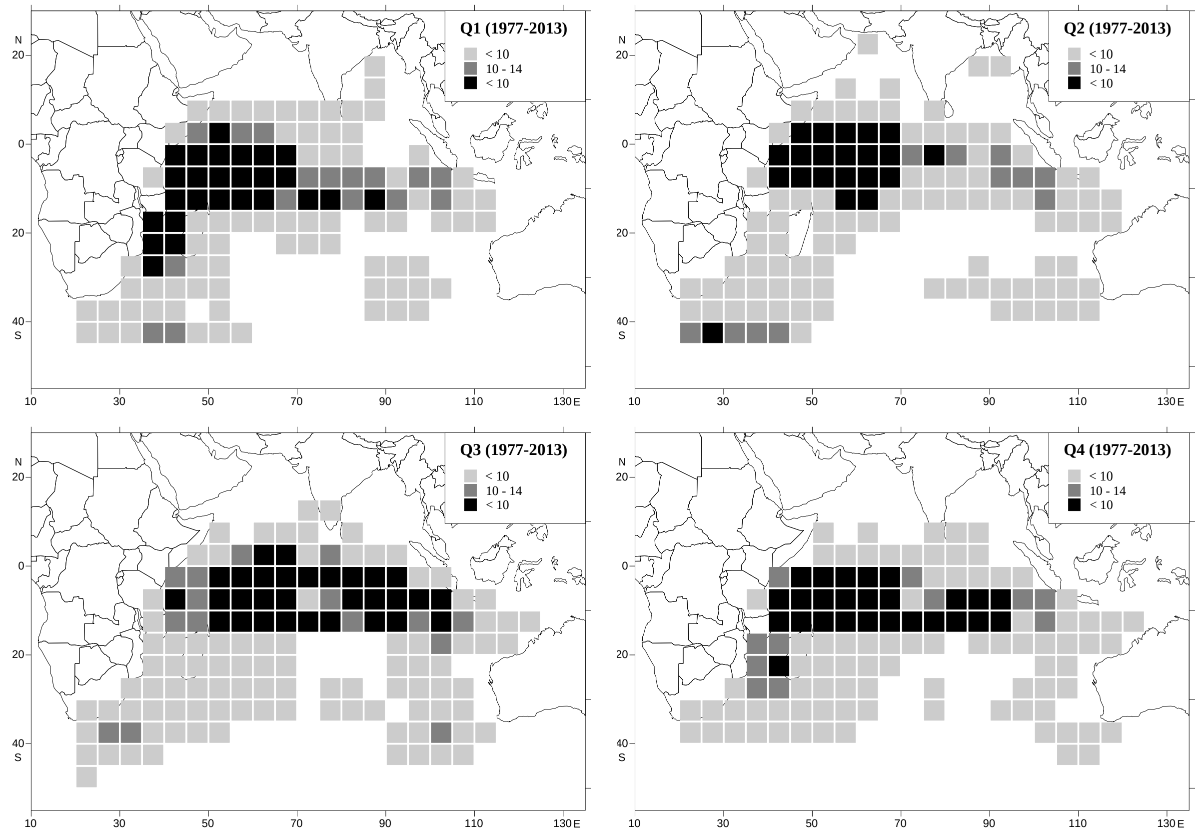


Fig. 4. Map showing the core area of Korean tuna longline vessels fishing for albacore tuna in the Indian Ocean, 1977-2013.

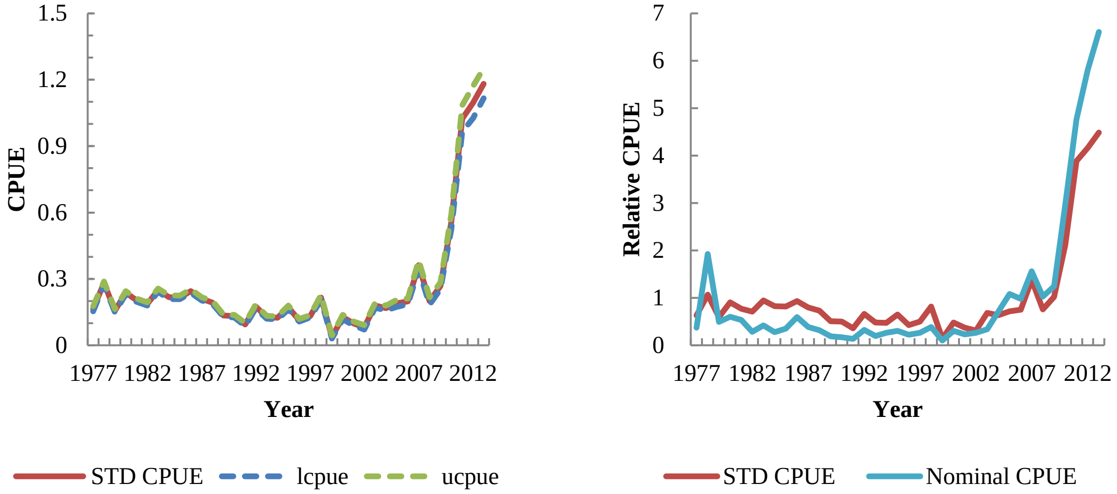


Fig. 5. Standardized (STD) and nominal CPUEs of albacore tuna for the whole area of Korean tuna longline fishery in the Indian Ocean, 1977-2013.

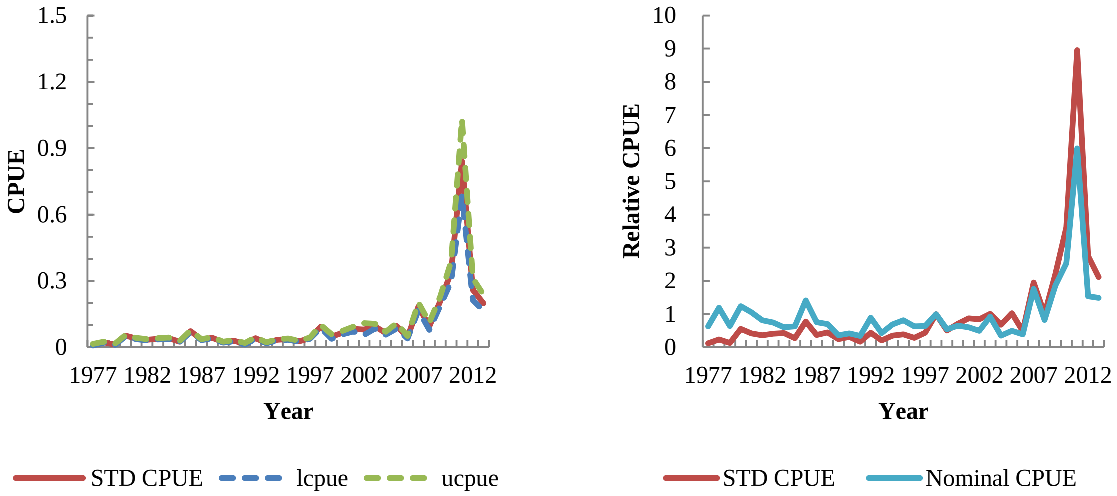


Fig. 6. Standardized (STD) and nominal CPUEs of albacore tuna for the core area (case 1) of Korean tuna longline fisheries in the Indian Ocean, 1977-2013.

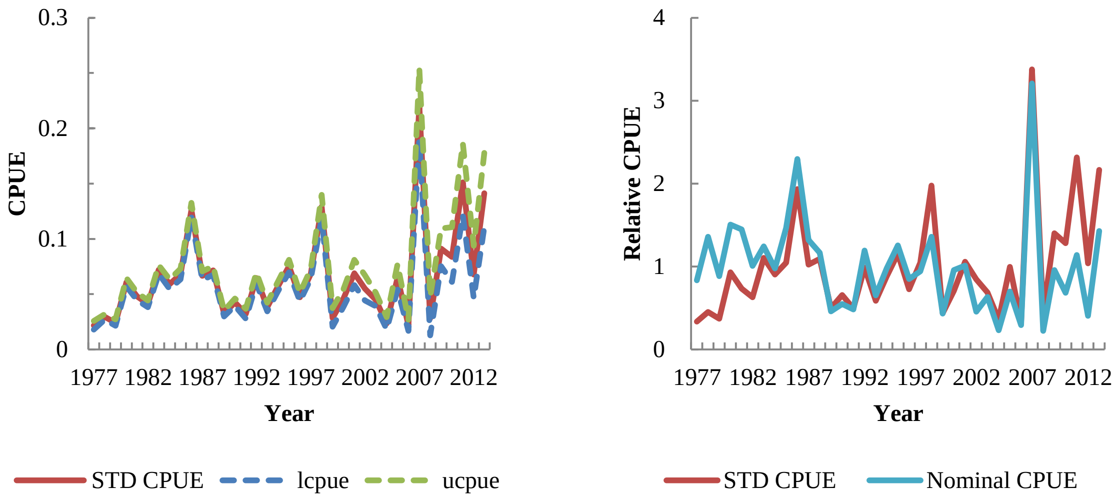
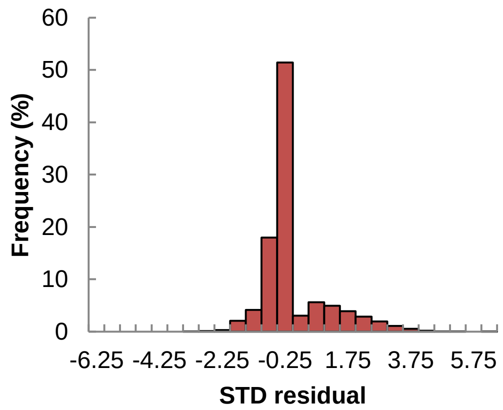
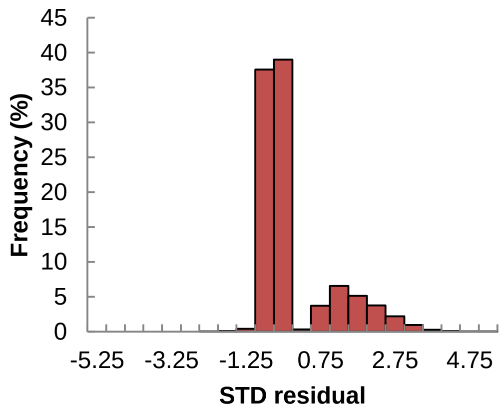


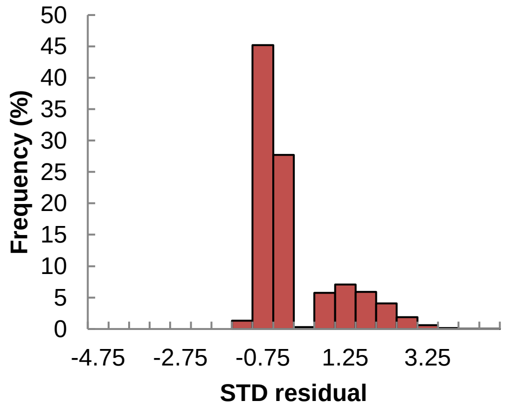
Fig. 7. Standardized (STD) and nominal CPUEs of albacore tuna for the core area (case 2) of Korean tuna longline fisheries in the Indian Ocean, 1977-2013.



(a) Whole area

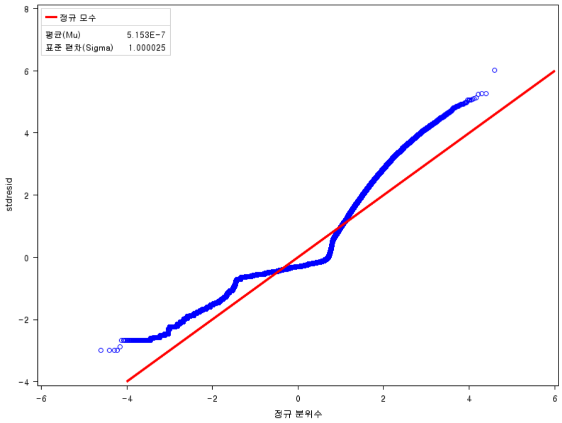


(b) Core area (case 1)

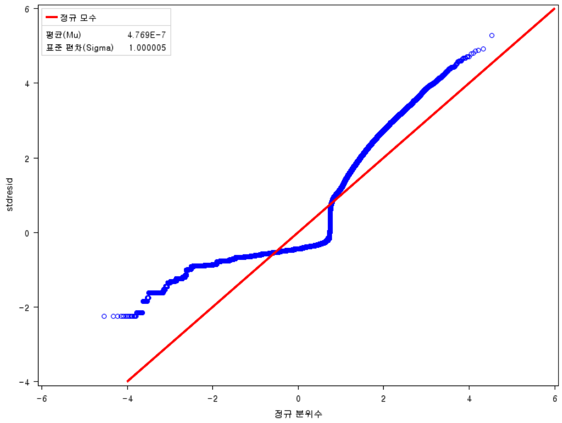


(c) Core area (case 2)

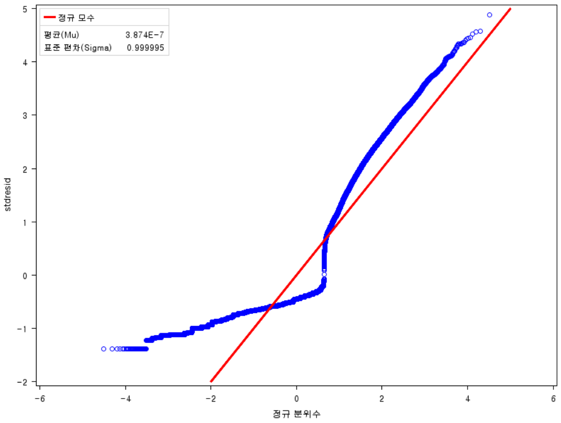
Fig. 8. Distribution of the standardized residual for the GLM analyses.



(a) Whole area

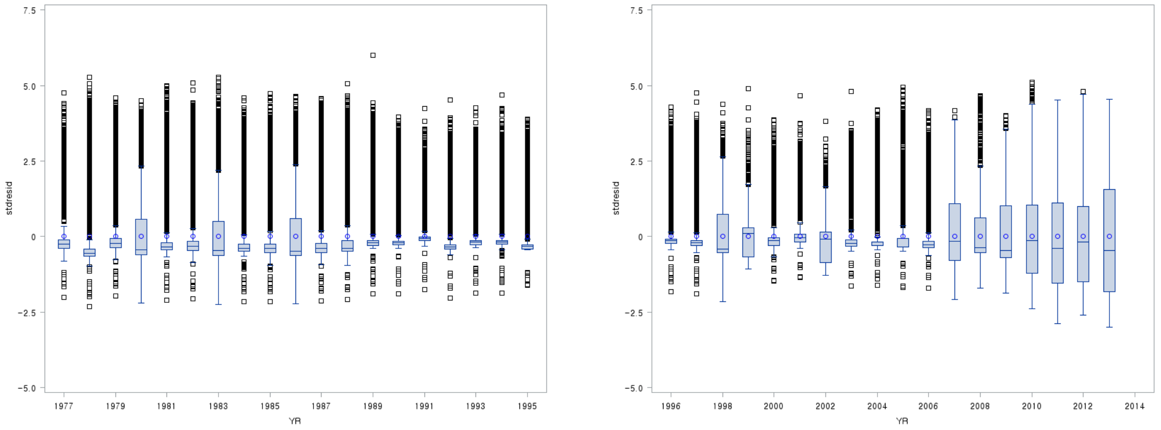


(b) Core area (case 1)



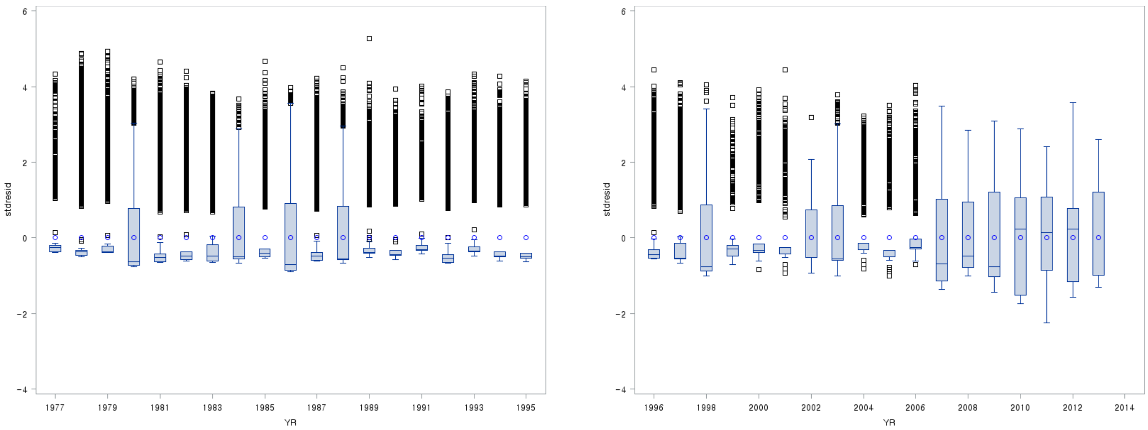
(c) Core area (case 2)

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

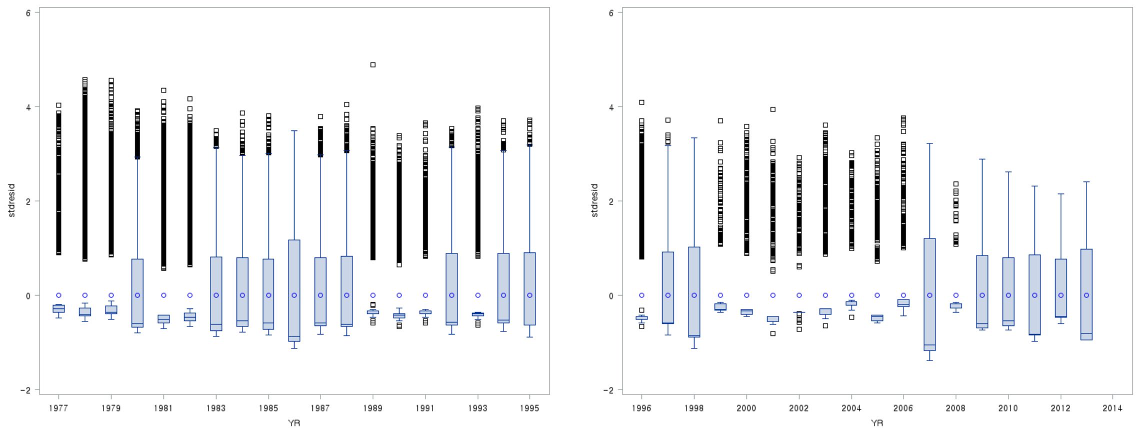


(a)

(a) Whole area



(b) Core area (case 1)



(c) Core area (case 2)

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 (interquartile range) above 75th percentile and 1.5 IQR below 25th percentile, squares: outliers.

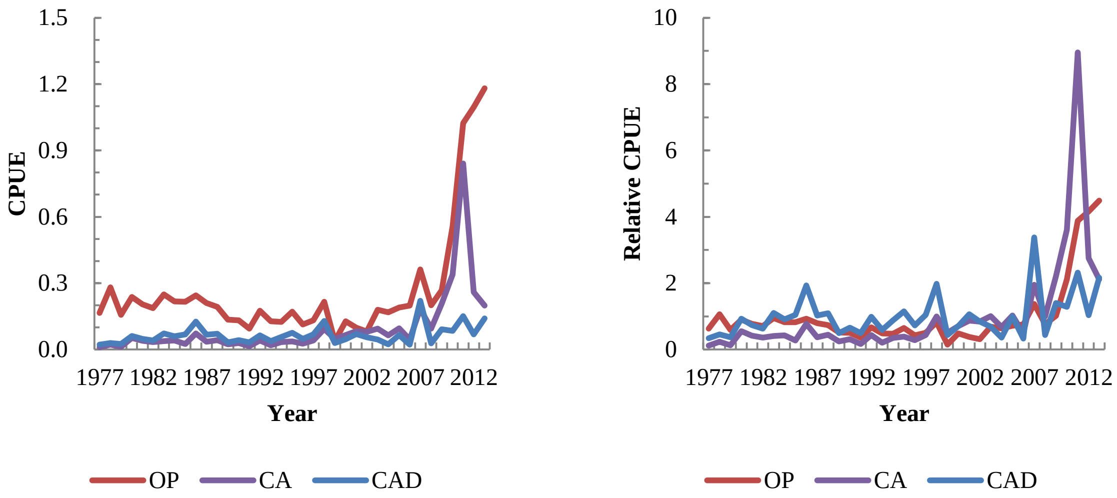


Fig. 11. Comparison of the standardized CPUEs of albacore tuna for the whole area (OP), the care area (case 1, CA), and the core area (case 2, CAD) of Korean tuna longline fishery, 1977-2013.

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

(a) Whole area

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	53	75567.218	1425.7966	1269.14	<.0001
Error	299182	336110.58	1.1234		
Corrected Total	299235	411677.8			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.183559	-74.36934	1.059921	-1.425212

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	36	17428.454	484.12373	430.93	<.0001
QR	3	505.58664	168.52888	150.01	<.0001
A	1	13605.98	13605.98	12111.1	<.0001
G	2	1121.2391	560.61953	499.02	<.0001
QR*A	3	755.30412	251.76804	224.11	<.0001
A*G	2	1852.2355	926.11777	824.36	<.0001
QR*G	6	804.35596	134.05933	119.33	<.0001

(b) Core area (case 1)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	12750.4	271.2851	154.14	<.0001
Error	215360	379024.11	1.76		
Corrected Total	215407	391774.51			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.032545	-59.04566	1.326633	-2.246792

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	36	9915.8905	275.4414	156.5	<.0001
QR	3	840.43438	280.14479	159.18	<.0001
G	2	1017.1878	508.59391	288.98	<.0001
QR*G	6	238.82377	39.803961	22.62	<.0001

(c) Core area (case 2)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	13830.64	294.2689	135.86	<.0001
Error	193930	420059.13	2.166		
Corrected Total	193977	433889.77			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.031876	-64.79991	1.471746	-2.271215

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	36	10467.068	290.75189	134.23	<.0001
QR	3	490.72788	163.57596	75.52	<.0001
G	2	200.48097	100.24048	46.28	<.0001
QR*G	6	698.13684	116.35614	53.72	<.0001

Table 2. Nominal and Standardized CPUEs, with the standard error, of albacore tuna of Korean tuna longline fishery in the Indian Ocean, 1977-2013.

(a) Whole area

Year	Nominal CPUE	STD CPUE	Standard Error
1977	0.5047	0.1650	0.0190
1978	2.5868	0.2808	0.0096
1979	0.6640	0.1563	0.0126
1980	0.8075	0.2378	0.0100
1981	0.7145	0.2037	0.0109
1982	0.3833	0.1869	0.0106
1983	0.5615	0.2490	0.0102
1984	0.3704	0.2167	0.0125
1985	0.4762	0.2164	0.0123
1986	0.7971	0.2452	0.0109
1987	0.5153	0.2100	0.0106
1988	0.4276	0.1928	0.0100
1989	0.2517	0.1346	0.0098
1990	0.2311	0.1314	0.0109
1991	0.1790	0.0943	0.0171
1992	0.4400	0.1753	0.0141
1993	0.2630	0.1271	0.0127
1994	0.3566	0.1240	0.0124
1995	0.4130	0.1710	0.0141
1996	0.2993	0.1129	0.0116
1997	0.3536	0.1313	0.0107
1998	0.5180	0.2158	0.0161
1999	0.1332	0.0374	0.0219
2000	0.4072	0.1273	0.0209
2001	0.3129	0.0986	0.0197
2002	0.3592	0.0812	0.0232
2003	0.4568	0.1797	0.0174
2004	0.9511	0.1679	0.0183
2005	1.4500	0.1896	0.0245
2006	1.3131	0.1985	0.0206
2007	2.1015	0.3624	0.0218
2008	1.3798	0.2002	0.0246
2009	1.6732	0.2682	0.0197
2010	3.9874	0.5569	0.0252
2011	6.4007	1.0230	0.0266
2012	7.7989	1.0962	0.0300
2013	8.8799	1.1818	0.0264

(b) Core area (case 2)

Year	Nominal CPUE	STD CPUE	Standard Error
1977	0.3780	0.0219	0.0294
1978	0.6164	0.0295	0.0172
1979	0.4014	0.0242	0.0217
1980	0.6827	0.0608	0.0179
1981	0.6560	0.0480	0.0192
1982	0.4569	0.0412	0.0184
1983	0.5636	0.0722	0.0174
1984	0.4427	0.0590	0.0215
1985	0.6656	0.0682	0.0213
1986	1.0421	0.1261	0.0190
1987	0.5990	0.0666	0.0181
1988	0.5281	0.0714	0.0172
1989	0.2085	0.0324	0.0170
1990	0.2484	0.0427	0.0191
1991	0.2187	0.0322	0.0299
1992	0.5416	0.0645	0.0234
1993	0.2966	0.0383	0.0233
1994	0.4425	0.0573	0.0216
1995	0.5695	0.0753	0.0244
1996	0.3855	0.0473	0.0206
1997	0.4271	0.0683	0.0191
1998	0.6165	0.1290	0.0307
1999	0.1957	0.0285	0.0577
2000	0.4348	0.0461	0.0446
2001	0.4585	0.0691	0.0513
2002	0.2072	0.0552	0.0580
2003	0.2868	0.0449	0.0345
2004	0.1051	0.0235	0.0407
2005	0.3162	0.0650	0.0530
2006	0.1337	0.0218	0.0391
2007	1.4548	0.2203	0.0612
2008	0.1018	0.0283	0.1206
2009	0.4350	0.0913	0.0636
2010	0.3095	0.0836	0.0974
2011	0.5161	0.1511	0.0836
2012	0.1835	0.0677	0.1060
2013	0.6482	0.1412	0.0917