Southern bluefin tuna CPUE standardization of the Korean tuna longline fisheries (1996-2012)

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Abstract

In this study, southern bluefin tuna, *Thunnus maccoyii* (SBT) CPUE standardization of Korean tuna longline fisheries (1996-2012) was conducted by Generalized Linear Model (GLM) using operational data to assess the proxy of the abundance index. The data used for GLM were catch (number) and 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 fishing for SBT. SBT CPUE was standardized for the whole area and the core area. Explanatory variables for the GLM analyses are year, season, area and HBF. GLM results for the whole area suggested that area and year effects were the largest factors affecting the nominal CPUE. The standardized CPUEs for both the whole area and the core area decreased until the mid-2000s and were showing the increasing trend since then.

1. Introduction

Korean tuna longline fisheries started targeting southern bluefin tuna, *Thunnus maccoyii* (SBT) in 1991. The catch was low at the beginning but increased to 1,320 mt in 1996, peaked at 1,796 mt in 1998, and thereafter largely decreasing down to below 200 mt in the mid-2000s. In 2008, the catch increased again up to 1,134 mt and thereafter fluctuated in a range of 705-1,117 mt due to the national catch limit. The catch of 2012 was 922 mt (Fig. 1). The number of longline vessels in active fishing for SBT was fluctuated between 4 and 19 from 1996 to 2010. Since 2011, 7 vessels have been operating in active for fishing SBT (Fig. 1).

Korean tuna longline vessels fishing for SBT have mainly operated in the south of 35°S between 10°E-50°E (area 9) and between 90°E-120°E (area 8), of which mainly in the western part (area 9) from March to July/August and in the eastern part (area 8) from July/August to December. In general, efforts for fishing SBT were concentrated relatively higher on the western part than on the eastern part (Kim et al, 2013).

In this study, SBT CPUE standardization of Korean tuna longline fisheries (1996-2012) was conducted using Generalized Linear Model (GLM) to assess the proxy of the abundance index.

2. Data and Methods

Operational data (set by set) for catch (number) and effort (number of hooks), HBF (number of hooks between floats) by year, month and area (1996-2012) were used for SBT CPUE standardization. The data prior to 1996 were not used in this study as Korean tuna longline fisheries had not targeted SBT, and hence the data were not available enough to carry out this analysis.

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 (Lee et al., 2012).

For area definition for SBT CPUE standardization, SBT statistical areas managed by the CCSBT were stratified into 12 areas, excluding 3 areas (areas 11-13), of which two areas were used in this study. Two areas were that one was area 9 (the main area) and other area included areas 1, 2, 7, 8, 14 and 15, because there were a lot of missing data (no operations) in some areas and some seasons. Furthermore, we combined the data of 12 months into 2 seasons (by a half year) likewise the combination of areas that were combined into 2 large areas for SBT CPUE standardization.

SBT CPUE was standardized for the whole area and the core area. To explore the core area where vessels have mainly operated to fish for SBT, we analysed the frequency of fishing year when there was 1 SBT or more caught by $5^{o}\times5^{o}$ area. In this study, the core area was defined as the area where fishing for SBT had occurred 10 times or more in same area during 1996-2012.

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

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

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

where, CPUE : catch in number of southern bluefin 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 (2 areas)
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
error : error term

3. Results and Discussion

3.1 Core area

Fig. 2 shows the frequency of fishing year by quarter for Korean tuna longline vessels fishing for SBT during 1996-2012. In the 1st quarter, the core area was formed at the 40^o-44^oS between 35^o-44^oE (area 9) and its size was smaller than those of other seasons. In the 2nd quarter, the core area was extended from 5^oE to 44^oE (area 9), and a large amount of SBT in a year was caught by Korean tuna longline vessels in this season. In the 3rd quarter, 2 core areas were formed because some vessels fishing for SBT were moved from the western part off South Africa (area 9) to the eastern part off the Western Australia (area 8). In the 4th quarter, the core area was formed only at the eastern part off the Western Australia (area 8), which was smaller in the area size.

3.2 CPUE standardization

Table 1 shows the ANOVA (type 3) for the GLM results which suggest that effects of all explanatory variables for the whole area model are significant, and area and year effects are the largest factors affecting the nominal CPUE.

Fig. 3 shows the standardized CPUE trends for the whole area of Korean tuna longline vessels fishing for SBT with nominal CPUE both in the real and relative scale, respectively. The standardized CPUE was about 2.6 in 1996, but it had decreased to 0.9 in 2004. Since then it has been showing an increasing trend with 3.5 in 2012. Both the standardized and nominal CPUEs showed a similar trend in general except for those of 2003, 2006 and 2011 showing a jump and a drop, but there are differences in the real scale between the standardized and nominal CPUEs.

The standardized CPUE for the core area of Korean tuna longline vessels fishing for SBT is shown in Fig. 4. The standardized CPUE was about 5.0 in 1996, and then showed a decreasing trend except a big jump in 2003. Since then they have been showing an increasing trend likewise those of the whole area.

Fig. 5 shows comparison of standardized CPUEs between the whole area and the core area. Both these CPUEs decreased until the mid-2000s, but thereafter they have been showing an increasing trend. However, the standardized CPUE for the core area showed a big jump in 2003 when it was different from that of the whole area but it was similar to the nominal CPUE. It was suggested that GLM for the core area did not significantly affect the nominal CPUE, the reason of which was likely that most efforts of Korean tuna longline vessels fishing for SBT have been concentrated on particular areas.

Figs. 6, 7 and 8 show the diagnostics for the GLM analyses that are frequency distributions, QQ-plots and box plots of the standardized residuals, respectively, which suggested that the data fit to the GLM fairly well.

References

Kim, Z.G., S.I. Lee, S.C. Yoon and D.W. Lee. 2013. 2013 Annual National Report of Korean SBT Fishery. CCSBT-ESC/1309/SBT Fisheries - Korea.

Lee, S.I., Z.G. Kim, M.K. Lee, D.W. Lee and T. Nishida. 2012. CPUE standardization for bigeye tuna caught by Korean tuna longline fisheries in the Indian Ocean (1978–2011). IOTC-2012-WPTT14-25.

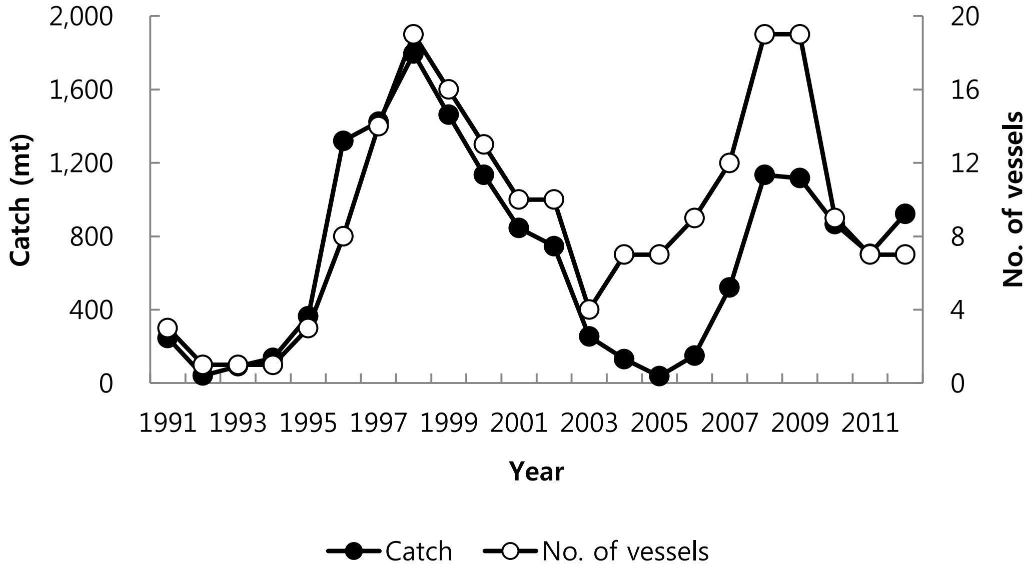


Fig. 1. The number of active Korean tuna longline vessels fishing for southern bluefin tuna (SBT) and their annual SBT catches in the CCSBT convention area, 1991-2012.

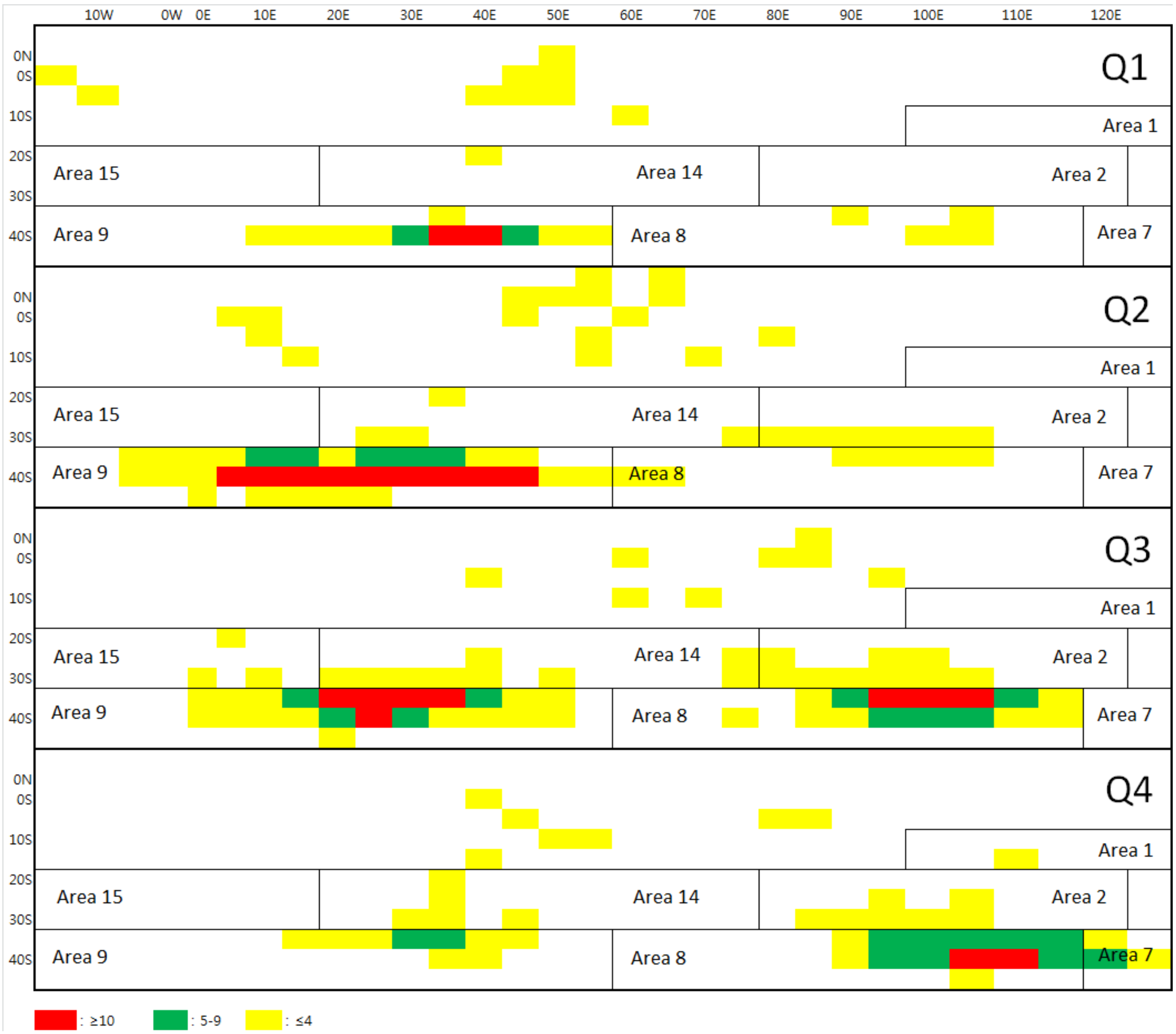


Fig. 2. Map showing the core area of Korean tuna longline vessels fishing for SBT.

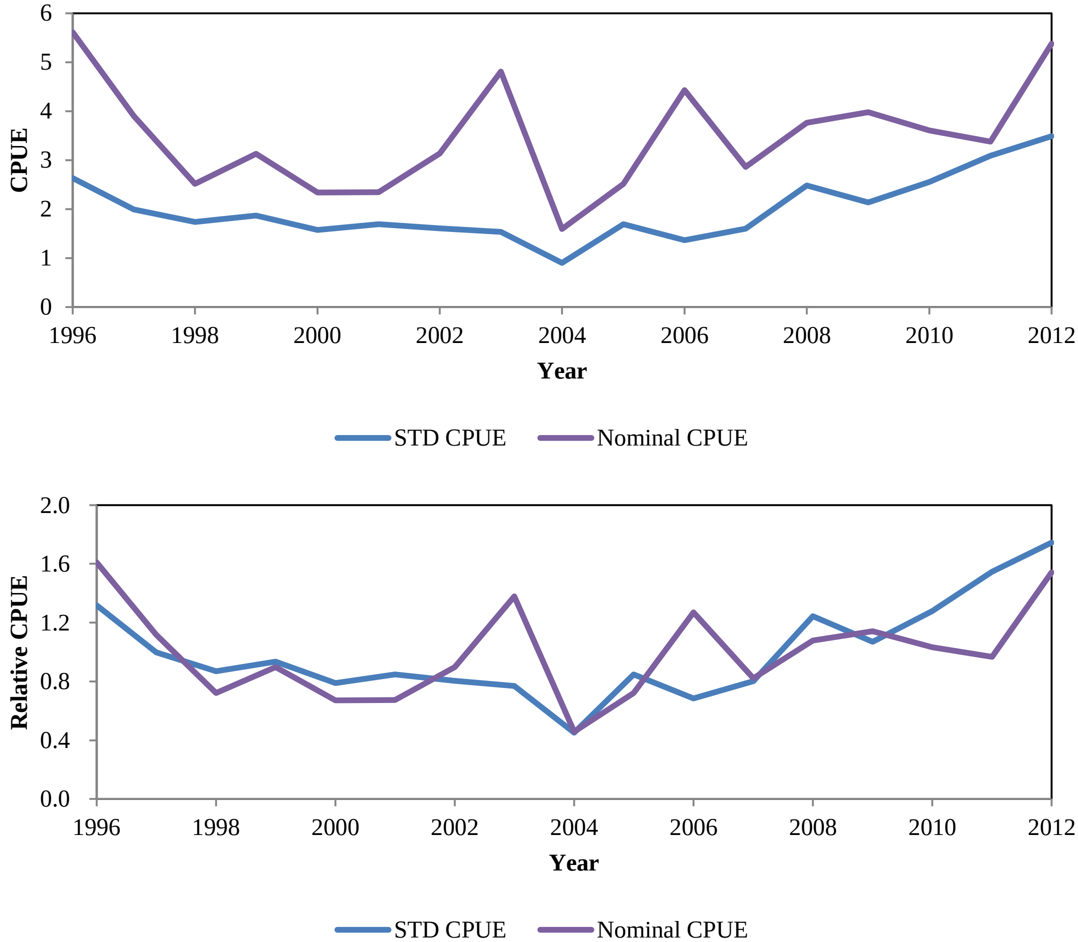


Fig. 3. SBT standardized (STD) and nominal CPUEs for the whole area of Korean tuna longline fisheries (1996-2012) (upper: real scale, lower: relative scale).

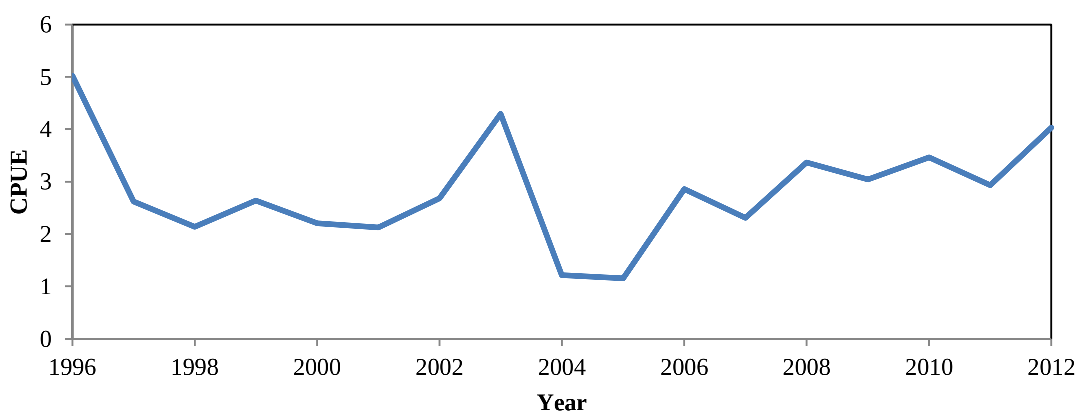


Fig. 4. SBT standardized CPUE for the core area of Korean tuna longline fisheries (1996-2012).

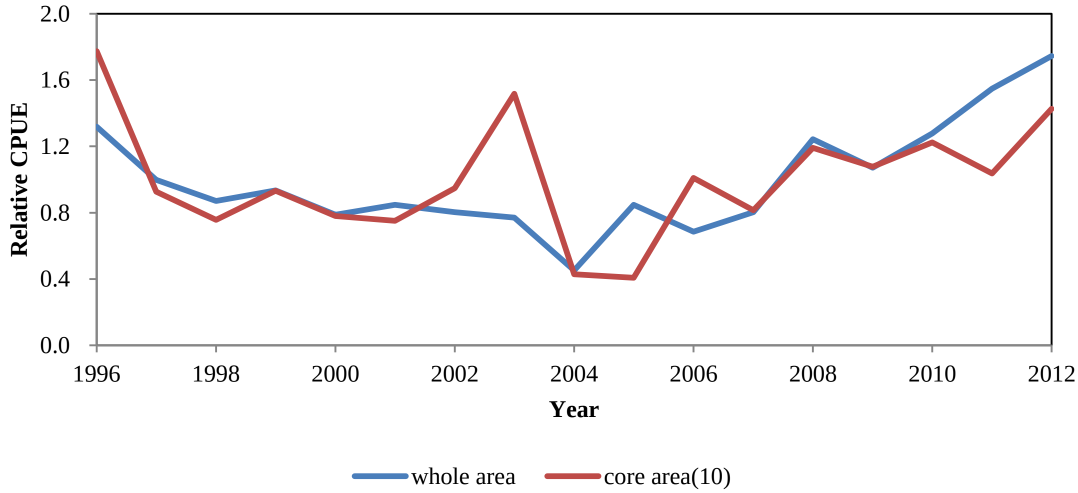


Fig. 5. Comparison of SBT standardized CPUEs for the whole area and the core area of Korean tuna longline fisheries (1996-2012) (upper: real scale, lower: relative scale).

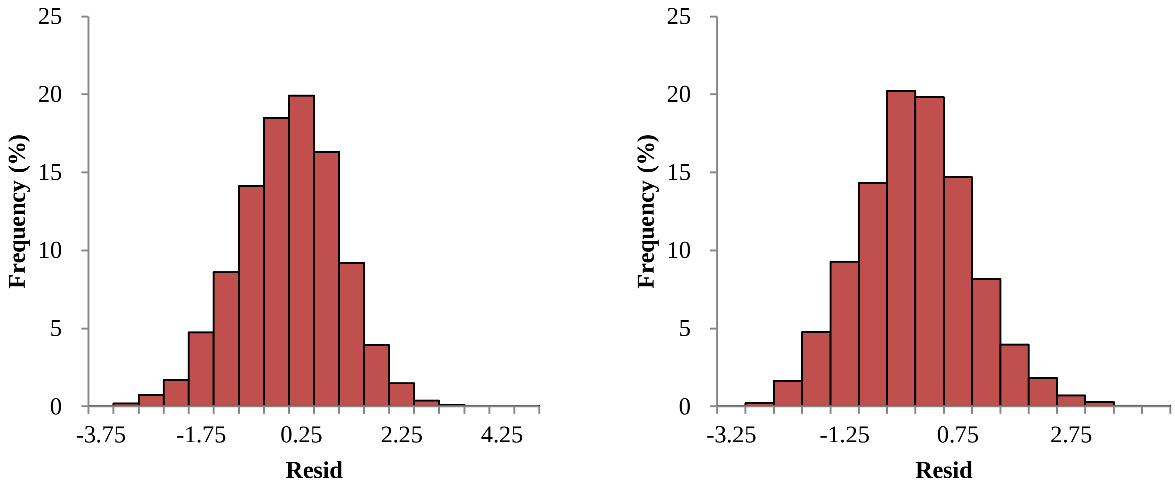


Fig. 6. Frequency distributions of the standardized residual for the GLM analyses (left: the whole area, right: the core area).

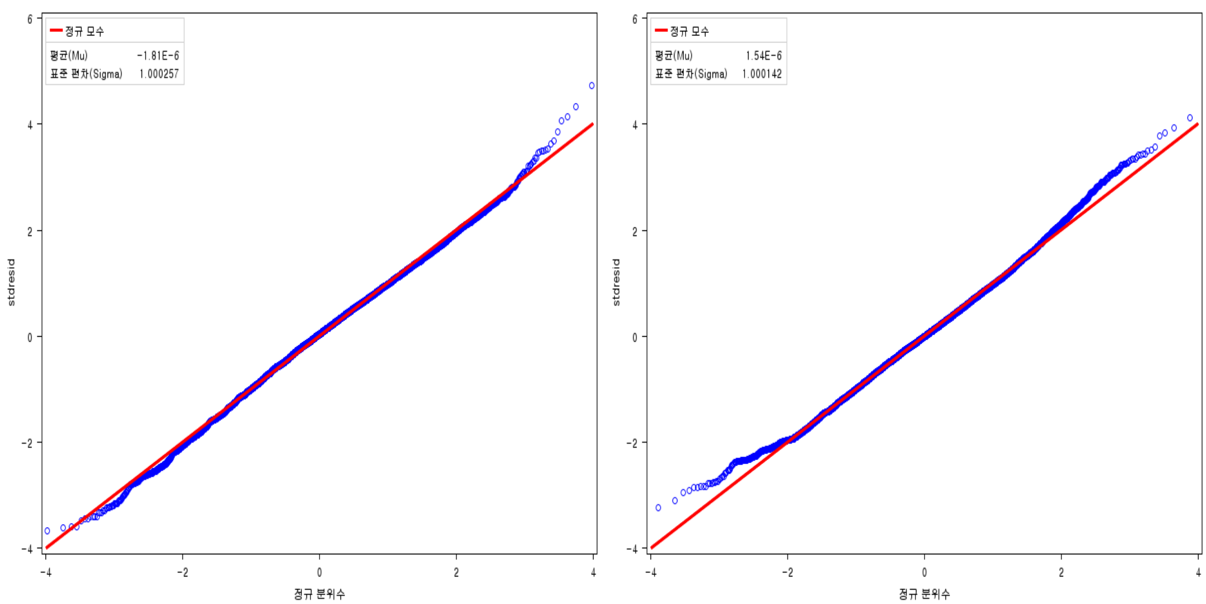
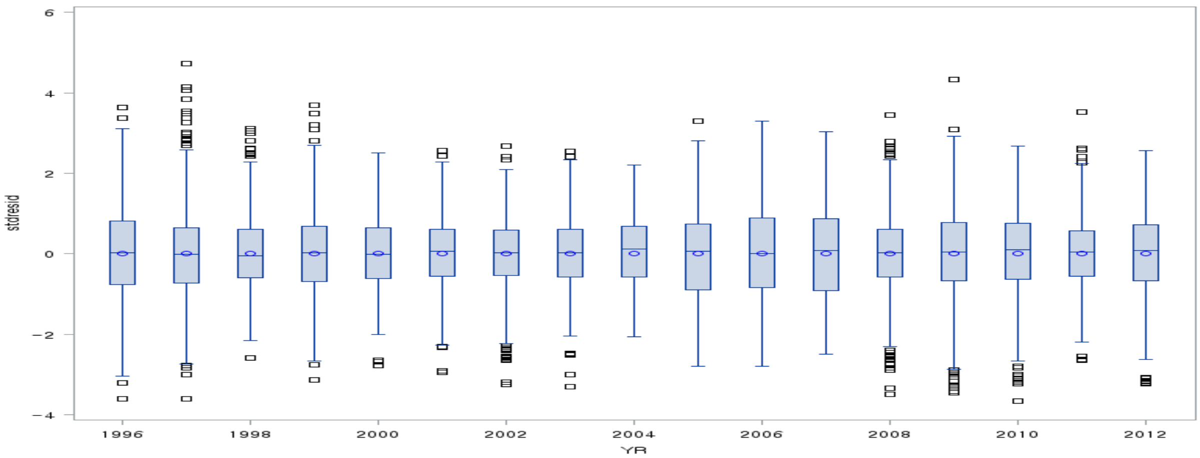


Fig. 7. QQ-plots of standardized residual for the GLM analyses (left: the whole area, right: the core area).



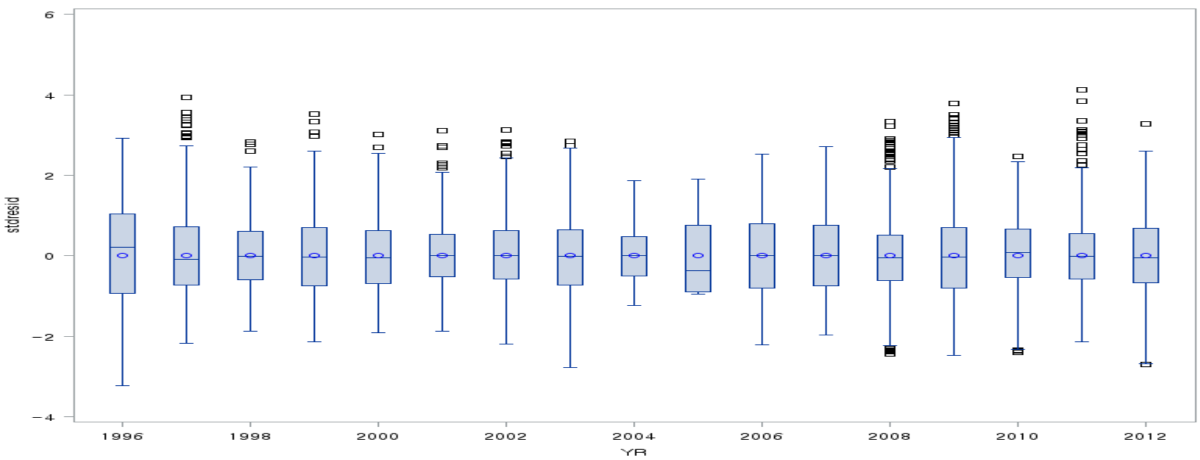


Fig. 8. Box plots of the stnadardized residual by year for the GLM analyses. Circle: mean, box: 25th and 75th percentile, horizontla line in the box: median, bars: maximum and minimum observation between 1.5 IQR (interqurtile range) above 75th percentile and 1.5 IQR below 25th percentile, squares: outliers (upper: the whole area, lower: the core area).

Table 1. ANOVA tables of GLM for SBT CPUE standardization

(a) the whole area

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	89	21931.051	246.4163	349.25	<.0001
Error	261023	184168.86	0.7056		
Corrected Total	261112	206099.91			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.10641	53.14966	0.83998	1.580404

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	35	7331.6266	209.47504	296.89	<.0001
S	1	103.928	103.928	147.3	<.0001
A	1	453.37557	453.37557	**642.57**	<.0001
G	4	521.55204	130.38801	184.8	<.0001
YR*A	35	988.04049	28.229728	40.01	<.0001
S*A	1	43.407703	43.407703	61.52	<.0001
S*G	4	100.36977	25.092444	35.56	<.0001
A*G	4	115.64131	28.910328	40.97	<.0001
S*A*G	4	132.93912	33.23478	47.1	<.0001

(b) the core area

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	662.33022	28.796966	58.68	<.0001
Error	12212	5993.4468	0.490783		
Corrected Total	12235	6655.7771			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.099512	63.97289	0.700559	1.095088

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	16	557.30218	34.831386	**70.97**	<.0001
S	1	0.0002787	0.0002787	0	0.981
G	3	19.281778	6.4272594	13.1	<.0001
S*G	3	38.127624	12.709208	25.9	<.0001