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CPUE standardization of bigeye 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 bigeye 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. Bigeye tuna CPUE by Korean tuna longline fishery was standardized for the whole, tropical and south areas. Although the trends of CPUE showed differences by area, since 1980s they had shown the declining trend until the early of 2000s, showed a steady trend with somewhat of increasing thereafter. In recent years, they showed a jump in 2011, but decreased again after that. However, the standardized CPUE for south area had a large fluctuation, especially after the early of 2000s.

Introduction

Bigeye tuna in the Indian Ocean has been one of the highest catch in Korean tuna longline fisheries along with yellowfin tuna. Bigeye catch considerably increased from the mid-1960s and peaked at about 34 thousands mt in 1978, but had decreased with a fluctuation to a few hundred tons in recent years (Fig. 1). In this study, bigeye CPUE (catch per unit effort) standardization of Korean tuna longline fisheries in the Indian Ocean (1977-2013) 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 bigeye 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 bigeye tuna (Langley et al., 2013), area was classified into 2 large areas for standardizing bigeye tuna CPUE of Korean tuna longline fishery (Fig. 2). The CPUE standardization was conducted for three cases which are whole area (R1+R2+R3), tropical area (R1+R2) and south area (R3).

Monthly data were combined into 2 seasons (by a half year). The reason is that there is missing values in some quarters.

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).

Generalized Linear Models (GLM) for bigeye tuna CPUE standardization for each area are as follows, and the analyses were conducted by SAS program (ver. 9.2).

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

Specific area (tropical and south): $\mathrm{Ln}(CPUE + c) = \mu + Y + S + G + Y\times S + S\times G + error$

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 (2 areas)

G: effect of gear (3 classes)

Y×A: interaction term between year and area

S×A: interaction term between season and area

A×G: interaction term between area and gear

S×G: interaction term between season and gear

S×A×G : interaction term among season, area and gear

error: error term

Results and Discussion

Fig. 3 shows the standardized CPUE trends of bigeye tuna for the whole area with nominal CPUE in real and relative scales. The standardized CPUE was about 3-4 from the mid-1970s to the mid-1980s, but since then it had shown the declining trend until the early of 2000s, and in recent years it is showing a steady trend with somewhat of increasing, especially in 2011 increased sharply but decreased again.

The standardized CPUE for tropical area was about 8.7 in 1977 and 1978, but it sharply decreased thereafter and showed the lowest value in 2002. After that it increased and showed a steady trend, especially which showed a big jump in 2011 and 2012 (Fig. 4).

For the south area, the standardized CPUE had the highest value in 1984, since then it had shown the declining trend until the early of 2000s as shown in the tropical area, but it is showing the increasing trend with large fluctuations in recent years (Fig. 5).

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.

Figs. 6, 7 and 8 show frequency distribution, Q-Q plots and box plots of the standardized residuals, respectively.

References

Langley, A., M. Herrera and R. Sharam, 2013. Stock assessment of bigeye tuna in the Indian Ocean for 2012. IOTC-2013-WPTT15-30 Rev_1, 1-36.

Lee, S.I., Z.G. Kim, J.E. Ku, M.K. Lee, H.W. Park, S.C. Yoon and D.W. Lee, 2014. Review of catch and effort for albacore tuna by Korean tuna longline fishery in the Indian Ocean (1965-2013). IOTC-2014-WPTmT05-17 Rev_1, 1-11.

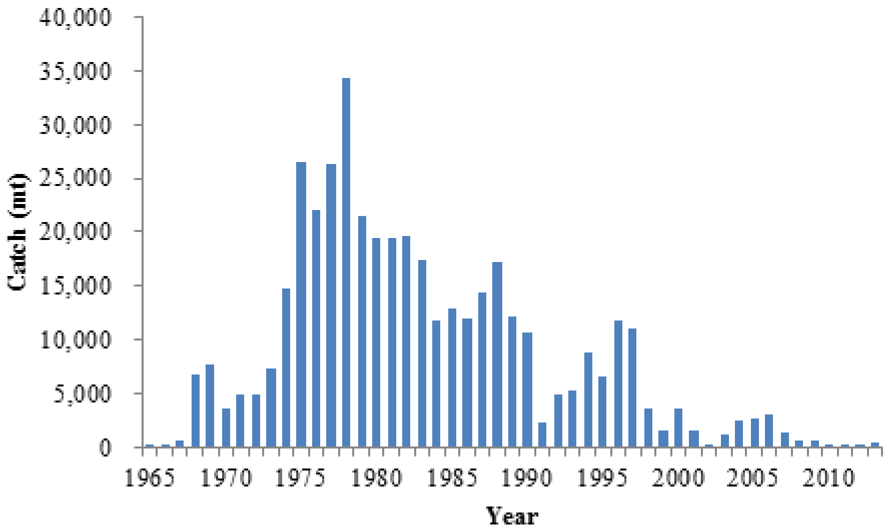


Fig. 1. Annual catch of bigeye tuna caught by Korean tuna longline fishery in the Indian Ocean, 1965-2013 (Data source: IOTC database).

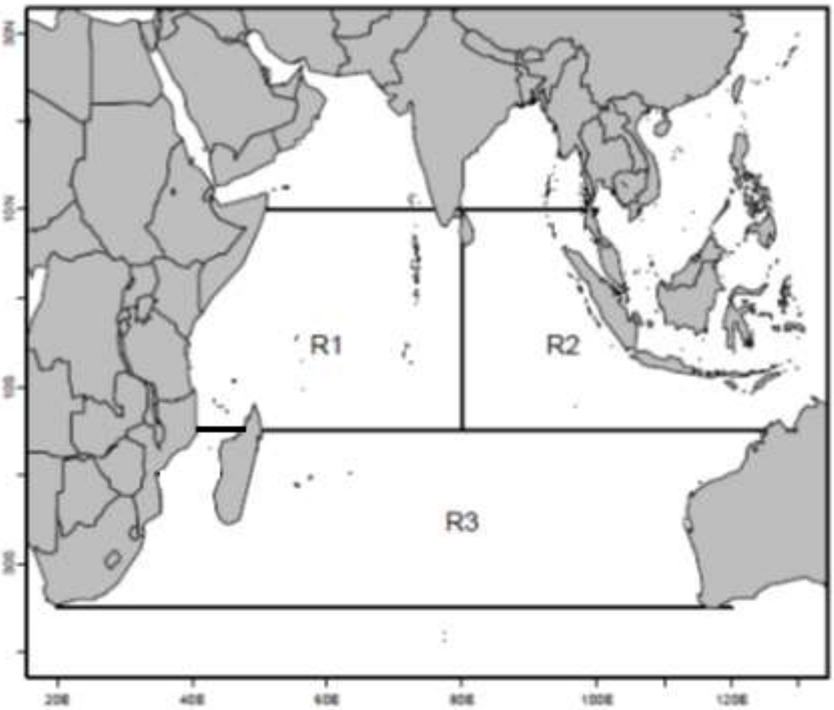


Fig. 2. Map showing areas used for bigeye tuna CPUE standardization of Korean tuna longline fishery in the Indian Ocean (tropical=R1+R2, south=R3).

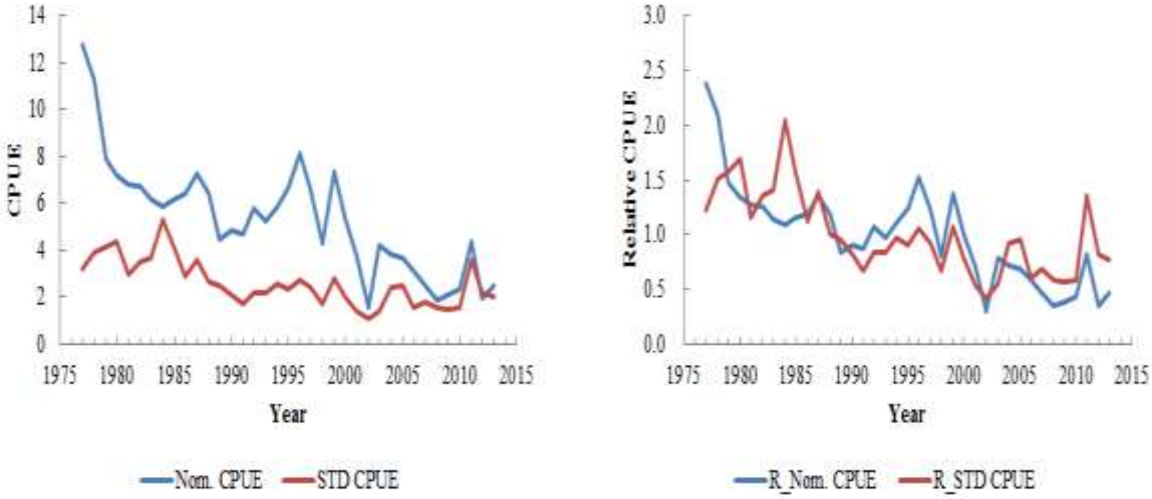


Fig. 3. Standardized (STD) and nominal CPUEs of bigeye tuna for the whole area of Korean tuna longline fishery in the Indian Ocean, 1977-2013.

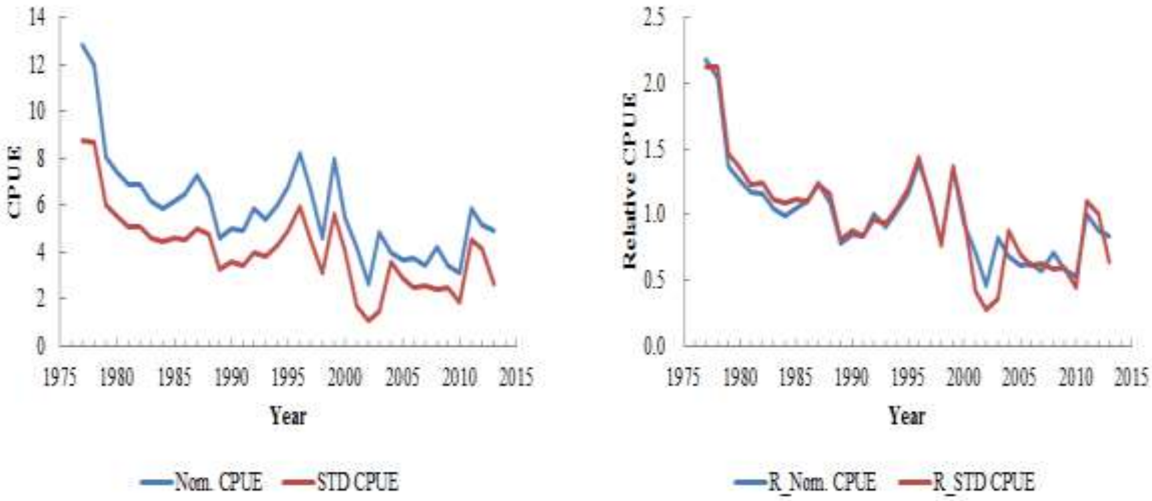
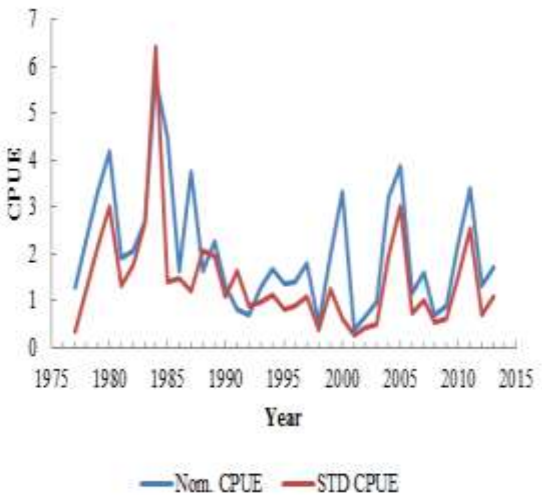


Fig. 4. Standardized (STD) and nominal CPUEs of bigeye tuna for the tropical area of Korean tuna longline fishery in the Indian Ocean, 1977-2013.



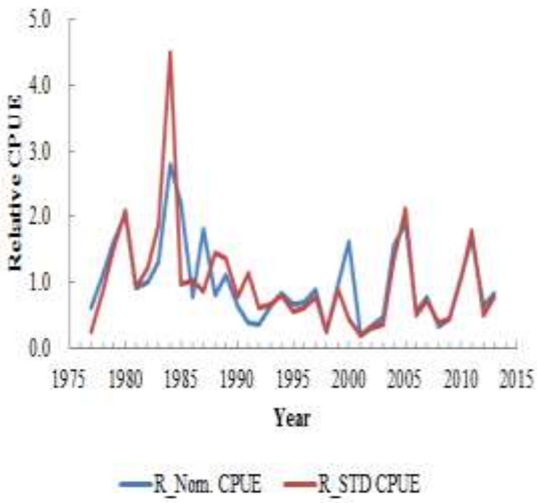
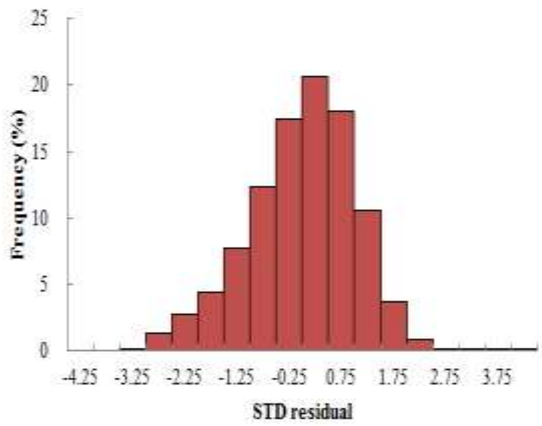
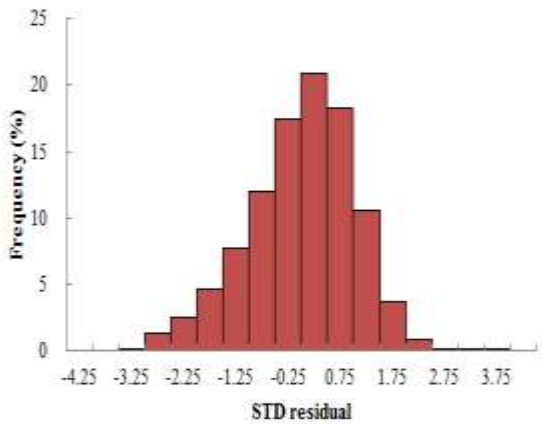


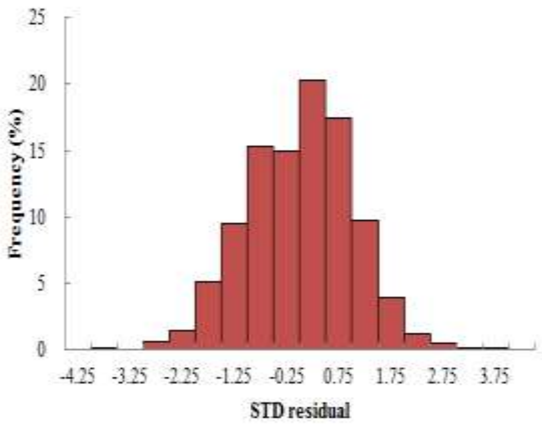
Fig. 5. Standardized (STD) and nominal CPUEs of bigeye tuna for the south area of Korean tuna longline fishery in the Indian Ocean, 1977-2013.



(a) Whole area

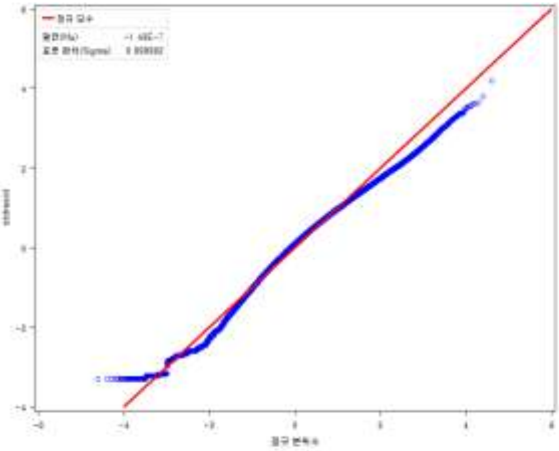


(b) Tropical area

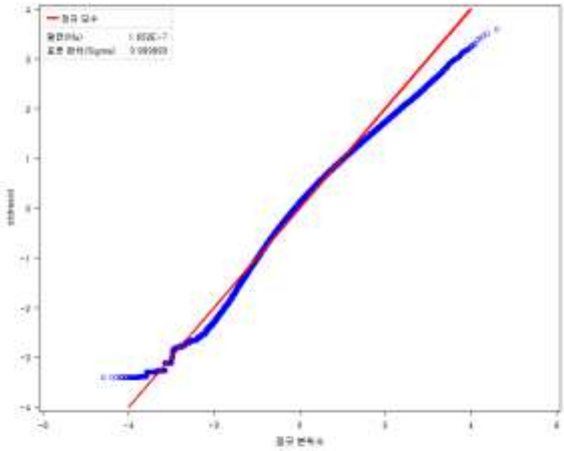


(c) South area

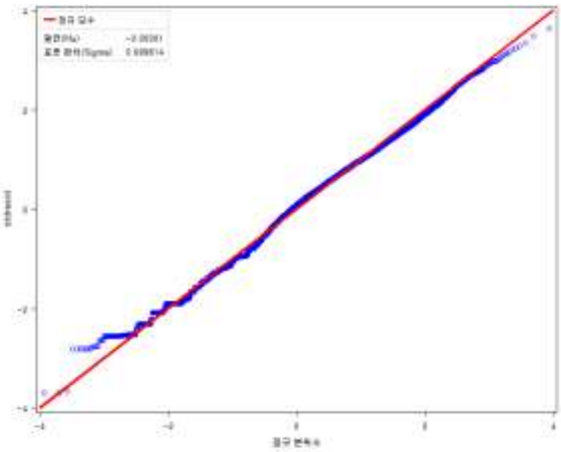
Fig. 6. Distribution of the standardized residual for the GLM analyses.



(a) Whole area

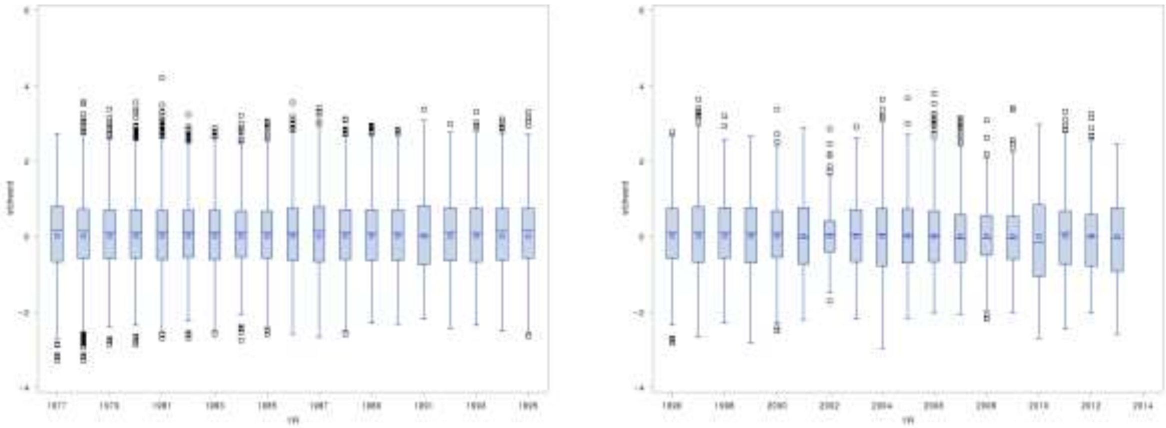


(b) Tropical area

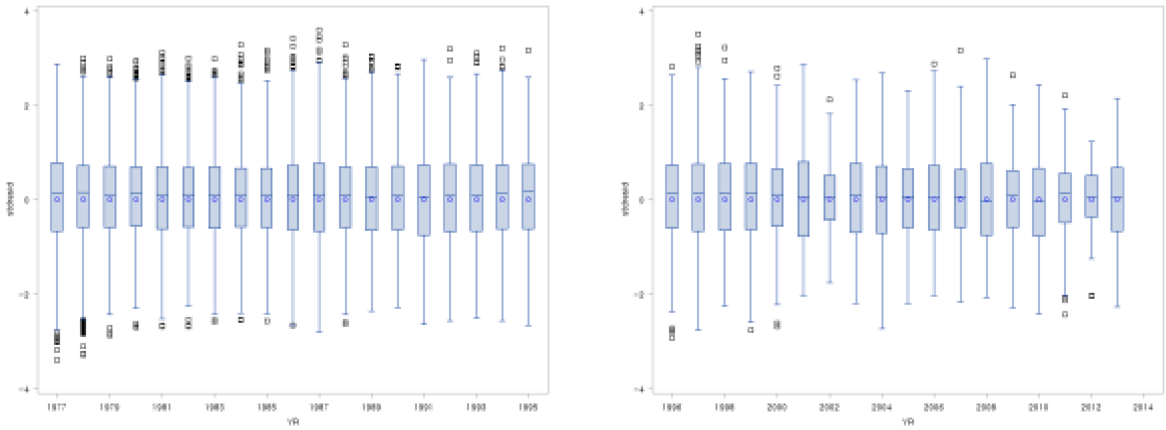


(c) South area

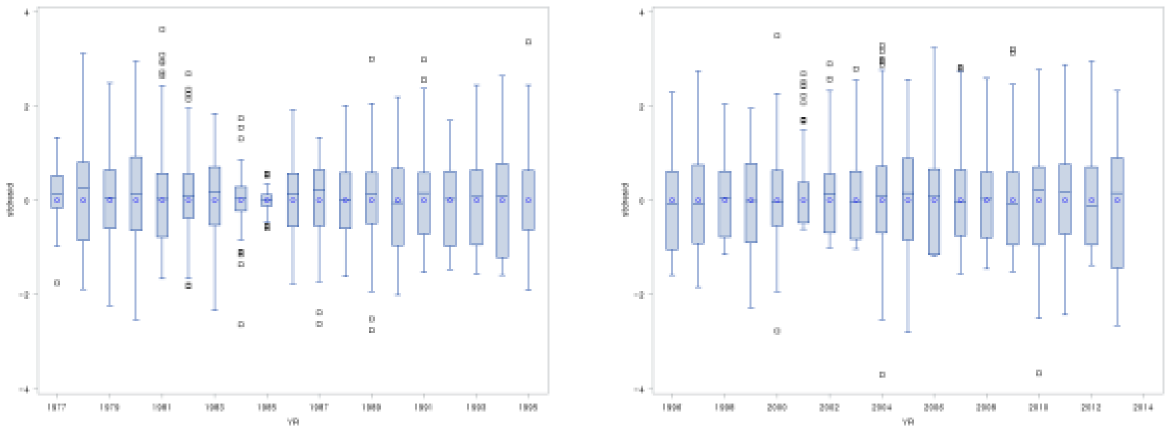
Fig. 7. QQ-plots of the standardized residual for the GLM analyses.



(a) Whole area



(b) Tropical area



(c) South area

Fig. 8. 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.

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	83	35708.932	430.2281	628.06	<.0001
Error	294042	201420.95	0.685		
Corrected Total	294125	237129.88			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.150588	51.11789	0.827652	1.619104

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	36	2848.6993	79.130536	115.52	<.0001
S	1	120.91898	120.91898	176.52	<.0001
A	1	503.64603	503.64603	735.24	<.0001
G	2	72.880865	36.440433	53.2	<.0001
YR*A	36	1553.0317	43.139768	62.98	<.0001
S*A	1	60.098942	60.098942	87.73	<.0001
A*G	2	46.259573	23.129787	33.77	<.0001
S*A*G	4	191.59536	47.89884	69.92	<.0001

(b) Tropical area

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	77	19113.424	248.2263	371.54	<.0001
Error	279143	186496.1	0.6681		
Corrected Total	279220	205609.52			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.09296	48.61276	0.817375	1.681401

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	36	11435.182	317.64396	475.44	<.0001
S	1	78.31684	78.31684	117.22	<.0001
G	2	9.24286	4.62143	6.92	0.001
YR*S	36	2937.1461	81.58739	122.12	<.0001
S*G	2	31.69741	15.84871	23.72	<.0001

(c) South area

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	77	5524.2933	71.74407	60.79	<.0001
Error	14827	17497.613	1.18012		
Corrected Total	14904	23021.906			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.239958	1321.332	1.086332	0.082215

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YR	36	2178.5328	60.5148	51.28	<.0001
S	1	97.311512	97.311512	82.46	<.0001
G	2	81.565002	40.782501	34.56	<.0001
YR*S	36	1486.1179	41.281054	34.98	<.0001
S*G	2	47.95566	23.97783	20.32	<.0001