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STANDARDIZATION ON NORTHERN ATLANTIC ALBACORE (*THUNNUS ALALUNGA*) CPUE, DATING FROM 1967 TO 2012, BASED ON TAIWANESE LONGLINE CATCH AND EFFORT STATISTICS

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SUMMARY

*The Taiwanese longline fisheries have been one of the major fleets operating in the North Atlantic for albacore resource since the mid-1960s. Catch statistics of North Atlantic albacore (*Thunnus alalunga*) compiled from Taiwanese longline fisheries from 1967 to 2012 were thus investigated in an attempt to elucidate the abundance fluctuations of this resource. The Taiwanese longline CPUE was separately standardized into three periods (1967~1987, 1987~1999 and 1999~2012). The generalized linear model (GLM) with log-normal error distribution was adopted for the standardization of both yearly and quarterly catch-per-unit-effort (CPUE) trends. Factors of year, quarter, subarea and bycatch effects of bigeye tuna, yellowfin tuna and swordfish were constructed into the model to obtain the yearly standardized abundance trend. Factors of quarter-series, subarea, and bycatch effects of bigeye tuna, yellowfin tuna and swordfish were constructed into the model to obtain quarterly the standardized abundance trend. The results show that the yearly standardized CPUE highly fluctuated before the mid-1980s, and then continuously declined up to the mid-1990s. Thereafter, it remained relatively stable up to the present. Similar trends were also obtained for the quarterly standardized CPUE series.*

RÉSUMÉ

*Les palangriers du Taipei chinois étaient l'une des principales flottilles opérant dans l'Atlantique Nord et ciblant le germon de l'Atlantique Nord depuis la moitié des années 60. Les statistiques de capture du germon de l'Atlantique Nord (*Thunnus alalunga*) provenant des pêcheries palangrières du Taipei chinois de 1967 à 2012 ont donc fait l'objet d'une étude en vue d'éclaircir les fluctuations de l'abondance de cette ressource. La CPUE palangrière du Taipei chinois a été standardisée séparément en trois périodes (1967-1987, 1987-1999 et 1999-2012). Le modèle linéaire généralisé (GLM) avec une distribution d'erreur log-normale a été adopté pour la standardisation des tendances annuelles et trimestrielles de capture par unité d'effort (CPUE). Les facteurs année, trimestre, sous-zone et effets de la capture accidentelle du thon obèse, de l'albacore et de l'espadon ont été inclus dans le modèle afin d'obtenir la tendance annuelle de l'abondance standardisée. Les facteurs de série trimestrielle, de sous-zone et d'effets de la capture accidentelle du thon obèse, de l'albacore et de l'espadon ont été inclus dans le modèle afin d'obtenir la tendance trimestrielle de l'abondance standardisée. Les résultats font apparaître que la CPUE standardisée annuelle fluctuait considérablement avant la moitié des années 80 et descendait ensuite de manière continue jusqu'à la moitié des années 90. Depuis lors, elle est restée à un niveau relativement stable jusqu'à présent. Des tendances similaires ont également été obtenues pour les séries des CPUE trimestrielles standardisées.*

RESUMEN

*Las pesquerías de palangre de Taipei Chino han sido de las más importantes en el Atlántico norte dirigidas al recurso de atún blanco del norte desde mediados de los sesenta. Las estadísticas de captura de atún blanco del Atlántico norte (*Thunnus alalunga*) recopiladas a partir de las pesquerías de palangre de Taipei Chino desde 1967 hasta 2012 se investigaron para intentar deducir las fluctuaciones en la abundancia de este recurso. La CPUE del palangre de Taipei Chino se estandarizó por separado en tres periodos (1967~1987, 1987~1999 y 1999~2012). Se adoptó el modelo lineal generalizado (GLM) con una distribución*

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de error lognormal para estandarizar las tendencias de la captura por unidad de esfuerzo (CPUE), tanto anuales como trimestrales. En el modelo se incluyeron los factores de año, trimestre, subárea y efectos de captura fortuita del patudo, rabil y pez espada para obtener la tendencia en la abundancia estandarizada anual. En el modelo se incluyeron los factores de series trimestrales, subárea y efectos de captura fortuita del patudo, rabil y pez espada para obtener la tendencia en la abundancia estandarizada trimestral. Los resultados demuestran que la CPUE estandarizada anual fluctuaba notablemente antes de mediados de los ochenta y más tarde descendió de forma continua hasta mediados de los noventa. Posteriormente, se mantuvo bastante estable hasta la actualidad. Se obtuvieron tendencias similares para la serie de CPUE estandarizada trimestral.

KEYWORDS

North Atlantic albacore, GLM, longline fisheries

Introduction

In the Atlantic Ocean, two stocks of albacore (*Thunnus alalunga*), separated by 5° N latitude, were assumed for the fishery management. Taiwan is one of the main fishing nations utilizing the north Atlantic albacore resource, and contributes a significant part to the total landings. As one of the main fishing nations, it is equally our responsibility to acquire the catch and effort statistics for the purpose of monitoring its status.

Taiwanese longliners operated in the Atlantic are mainly composed of two types of fishing gears, i.e., regular longliner and deep longliner. The former, which is also called traditional longliner, is mainly targeting on albacore, whereas the latter equipped with –70℃ freezing capability is mainly targeting on bigeye and yellowfin tunas. Unfortunately, it was not possible until mid-1990s when the logbook reporting system was able to directly distinguish their major identities by the addition of "the number of hooks per basket used" in logbook. However, historic task2 data series compiled by Taiwanese fisheries managerial sector and reported to the ICCAT since late-1960s thus became one of the important data sources to investigate the long-term abundance fluctuation of this resource.

The main purpose of this study was thus to obtain, based on Taiwanese 1967-2012 task2 data series, the longterm abundance trend of North Atlantic albacore resource by using GLM standardization procedure. Factors of quarter, fishing areas, and bycatch information were often adopted as remedies for better understanding the main factor of year component.

Materials and Methods

Taiwanese longline catch and effort data, compiled by month and by 5° square block, from 1967 to 2012 were the major source of data used in this analysis. These data were kindly provided by the Overseas Fisheries Development Council (OFDC), Taiwanese fisheries managerial sector.

GLM with normal error structure (Robson, 1966; Gavaris, 1980; Kimura, 1981) was used in the present study to standardize yearly and quarterly CPUE trends, based on Taiwanese longline fisheries data set, for the north Atlantic albacore. Factors of year, quarter, subarea and bycatch effects of bigeye tuna, yellowfin tuna and swordfish will be constructed for obtaining yearly standardized CPUE trend. Factors of quarter-series, subarea and bycatch effects of bigeye tuna, yellowfin tuna and swordfish will be constructed for obtaining quarterly standardized CPUE trend. Bycatch effects of bigeye tuna, yellowfin tuna and swordfish were evaluated by quartile. Three subareas (Figure 1), followed the resultant obtained by Yang and Yeh (2004), were adopted in the model to minimize variations caused by fishing location. The Taiwanese longline CPUE was separately standardized into three periods (1967~1987, 1987~1999 and 1999~2012). GLM models thus constructed for both yearly and quarterly standardizations are:

Yearly generalized linear model with normal error structure:

$$Log\ (U_{ijklmn} + C) = \mu + Y_i + Q_j + A_k + BE_l + YF_m + SW_n + \varepsilon_{ijklmn}$$

where *Log*: natural logarithm;

U_{ijklmn}: nominal CPUE in year i, quarter j, subarea k, and with bycatch level of BE_l, YF_m, SW_n
μ: intercept, or overall mean for correction
C: constant (10% of the overall mean albacore nominal CPUE)
Y_i: effect of year i
Q_j: effect of quarter j
A_k: effect of subarea k;
BE_l: bycatch effect of bigeye tuna in quartiles of CPUE (no./1000hooks)
YF_m: bycatch effect of yellowfin tuna in quartiles of CPUE (no./1000hooks)
SW_n: bycatch effect of swordfish in quartiles of CPUE (no./1000hooks)
ε: error term assumed fitting with normal distribution N(0,1).

Quarterly generalized linear model with normal error structure:

$$Log\ (U_{jklmn} + C) = \mu + YQ_j + A_k + BE_l + YF_m + SW_n + \varepsilon_{jklmn}$$

where *Log*: natural logarithm;
U_{jklmn}: nominal CPUE in quarter-series j, subarea k, and with bycatch level of BE_l, YF_m, SW_n
μ: intercept, or overall mean for correction
C: constant (10% of the overall mean of albacore nominal CPUE)
YQ_j : effect of quarter-series j
A_k: effect of subarea k
BE_l: bycatch effect of bigeye tuna in quartiles of CPUE (no./1000hooks)
YF_m: bycatch effect of yellowfin tuna in quartiles of CPUE (no./1000hooks)
SW_n: bycatch effect of swordfish in quartiles of CPUE (no./1000hooks)
ε: error term assumed fitting with normal distribution N(0,1).

SAS (Statistical Analysis System) Ver. 9.3 package was used to find solutions.

Results and Discussion

A constant (for three periods: 1967~1987, 1987~1999 and 1999~2012), which was obtained by averaging all Taiwanese longliners' nominal albacore CPUE reported in the north Atlantic and dividing by 10, was determined and added to each nominal albacore CPUE before using SAS solver for the purpose of avoiding zero albacore catch rate problem (ICCAT, 1996).

Around mid-1980s, some Taiwanese longliners began to equip with super cold freezer and shifted their target species from albacore to bigeye tuna in order to meet the demands of the sashimi markets. The increasing efforts of these deep longliners are thus considered as non-albacore-directed efforts, since albacore is the less expected catch species than bigeye tuna. Unfortunately, the traditional log book system cannot distinguish fishing efforts of regular albacore-targeting longliner from those of bigeye-targeting deep longliners. Although the situation got improved since mid-1990s when number of hooks per basket was added to the new log book system, historic log reports can only be distinguished, perhaps, by specification on area-time of fishing or catch composition.

Efforts (Yang and Yeh, 2004) have been devoted to subdivide North Atlantic into subareas for the purpose of sorting out a homogeneous subarea, by clustering analyses on catch composition, of showing indicative catch composition. The result of 3-subareas thus obtained indicated that the longline catch composition of subarea-1 was significantly different with the other two subareas. Longline catch in subarea-1, which is also the traditional fishing ground for North Atlantic albacore, were mainly comprised of albacore. On the other hand, longline catch in subarea-3 was mainly composed of big eye tuna thus to be considered as the major fishing ground for Taiwanese deep longliners targeting on bigeye tuna. As for subarea-2, there often appeared mixture catches of albacore, bigeye and yellowfin tunas each with various area-time intensities. To divide appropriately the north Atlantic albacore's entire habitat into subareas is one of the attempts used in the present study for providing corrections stemmed from area contrast. The character of subareas from the data set reflects that subarea-1 is the main fishing areas of albacore, subarea-3 for bigeye tuna, and subarea-2 for a mixture of albacore and bigeye tuna.

The standardization of CPUE trends for both the yearly series and quarterly series were constructed by GLM model. The results of ANOVA test for the yearly series show that either the model itself or the effects considered are all significant at 0.0001 confidence level (Table 1). As shown in the table, the effect of subarea plays the most important role in explanation of the model variation, and followed by effects of bigeye and quarter.

Comparatively, effects of year, yellowfin and swordfish play less important roles as their mean square are relatively low, but they are still statistically significant. Similar results of ANOVA are obtained for the quarterly series, and importance of the effects in explanation of the model variation ranks from subarea, bigeye, yellowfin, year-season and swordfish (Table 2).

The yearly nominal CPUE trend and its respective standardized CPUE series thus obtained were tabulated in Table 3, and plotted in Figure 2. The yearly standardized CPUE series showed a slight decline in the beginning of the fishery, and then fluctuated between 5 and 12 up to mid-1980s. Thereafter, a continuous decline was observed until 1996, and then it remained relative stable at a level between 2 and 7 no./1000 hooks. The normalized residual pattern from this model is shown in Figure 3. As shown in the figure, main distribution of residuals ranged from –1.00 to +1.00 and obviously centered at zero as mode. The Q-Q plot of those residuals was also shown in Figure 4, indicating the fitting was generally good.

The quarterly standardized CPUE series were also tabulated in Table 4, and plotted in Figure 5. In the period from 1967 to mid-1980s, the quarterly standardized CPUE series highly fluctuated mainly within a range between 4 and 14 no./1000 hooks. Then a continuous decline from late 1980s to mid 1990s was apparently observed. Thereafter, the CPUE trend remained relative stable ranging from 2 to 6 no./1000 hooks. The general trend appeared in quarterly CPUE series is very similar with those obtained in yearly CPUE trend. The normalized residual pattern from this model is shown in Figure 6. As shown in Figure 8, main distribution of residuals ranged from –1.00 to +1.00 and obviously centered at zero as mode. The Q-Q plot of those residuals were shown in Figure 7 indicating the fitting was generally good.

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Table 1. Analysis of variance on the standardized north Atlantic albacore yearly CPUE using Taiwanese longline fisheries data set from 1967 to 2012 (three periods:1967~1987, 1987~1999 and 1999~2012).

1. Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	34	1627.924089	47.88012	153.96	<.0001
Error	3391	1054.578806	0.310993		
Corrected Total	3425	2682.502895			
R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean		
0.606868	19.66674	0.557668	2.835588		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	20	68.4968216	3.4248411	11.01	<.0001
quarter	3	55.7437786	18.5812595	59.75	<.0001
subarea	2	616.8414993	308.4207496	991.73	<.0001
codebet	3	33.687908	11.2293027	36.11	<.0001
codeyft	3	6.0951214	2.0317071	6.53	0.0002
codeswo	3	10.0033007	3.3344336	10.72	<.0001

2. Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	23	2564.191505	111.486587	164.96	<.0001
Error	1862	1258.400126	0.675833		
Corrected Total	1885	3822.591631			
R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean		
0.670799	52.76559	0.82209	1.558004		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	12	108.807072	9.067256	13.42	<.0001
quarter	3	15.6410415	5.2136805	7.71	<.0001
subarea	2	309.8926703	154.9463351	229.27	<.0001
codebet	3	267.7324208	89.2441403	132.05	<.0001
codeyft	3	24.3709766	8.1236589	12.02	0.0002

3. Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	26	4217.651167	162.217353	260.57	<.0001
Error	2901	1806.035126	0.622556		
Corrected Total	2927	6023.686293			
R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean		
0.700178	61.5629	0.789022	1.281652		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	13	115.6797442	8.8984419	14.29	<.0001
quarter	3	51.0923428	17.0307809	27.36	<.0001
subarea	2	596.60831	298.304155	479.16	<.0001
codebet	3	466.0344519	155.3448173	249.53	<.0001
codeyft	3	12.9376258	4.3125419	6.93	0.0001
codeswo	2	8.7517607	4.3758804	7.03	0.0009

Table 2. Analysis of variance on the quarterly standardized CPUE based on northern Atlantic albacore data of Taiwanese longline fishery during 1967 to 2012 (three periods:1967~1987, 1987~1999 and 1999~2012).

1. Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	92	1683.030435	18.293809	61.01	<.0001
Error	3333	999.47246	0.299872		
Corrected Total	3425	2682.502895			
R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean		
0.62741	19.31188	0.547605	2.835588		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yq	81	177.2254812	2.1879689	7.3	<.0001
subarea	2	572.8552817	286.4276409	955.17	<.0001
codebet	3	32.7065675	10.9021892	36.36	<.0001
codeyft	3	6.5622981	2.1874327	7.29	<.0001
codeswo	3	8.9049156	2.9683052	9.9	<.0001

2. Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	59	2602.065162	44.102799	65.98	<.0001
Error	1826	1220.526468	0.668415		
Corrected Total	1885	3822.591631			
R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean		
0.680707	52.47525	0.817567	1.558004		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yq	51	163.2555456	3.2010891	4.79	<.0001
subarea	2	288.7721545	144.3860773	216.01	<.0001
codebet	3	250.5495642	83.5165214	124.95	<.0001
codeyft	3	24.9015027	8.3005009	12.42	<.0001

3. Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	65	4268.187674	65.664426	107.05	<.0001
Error	2862	1755.498619	0.613382		
Corrected Total	2927	6023.686293			
R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean		
0.708567	61.10761	0.783187	1.281652		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yq	55	208.9207159	3.7985585	6.19	<.0001
subarea	2	583.1000157	291.5500078	475.32	<.0001
codebet	3	431.7846597	143.9282199	234.65	<.0001
codeyft	3	12.0932717	4.0310906	6.57	0.0002
codeswo	2	7.5342054	3.7671027	6.14	0.0022

Table 3. The nominal CPUE and its respective yearly standardized CPUE of north Atlantic albacore based on the Taiwanese catch statistics from 1967 to 2012.

Year	Nominal CPUE 1	Nominal CPUE 2	Nominal CPUE 3	Standardized CPUE 1	Standardized CPUE 2	Standardized CPUE 3
1967	19.7391			7.04761149		
1968	16.0726			12.17957499		
1969	13.406			10.51884607		
1970	14.2848			9.34167880		
1971	10.5539			6.71437595		
1972	25.5395			7.06525616		
1973	26.5063			8.74580466		
1974	25.3519			7.98217959		
1975	27.4278			6.77497221		
1976	26.3591			9.36022324		
1977	23.6375			9.11781900		
1978	23.4746			8.69721275		
1979	30.2652			8.55978189		
1980	29.8619			8.82731190		
1981	27.7329			8.71087020		
1982	34.465			9.53825509		
1983	31.5084			9.54492836		
1984	27.5051			8.30930525		
1985	22.3687			7.17560262		
1986	19.5749			5.89185191		
1987	16.4646	16.4646		5.55517944	4.30222512	
1988		28.0238			6.98517469	
1989		19.0499			5.25506371	
1990		4.7679			3.85984828	
1991		6.0984			5.26785495	
1992		3.6641			4.45330957	
1993		10.2907			4.43557565	
1994		13.9695			3.22619959	
1995		14.5839			3.34505891	
1996		7.8009			2.19693177	
1997		8.3098			2.66303358	
1998		13.0828			2.66353052	
1999		6.9356	6.9356		2.02489370	2.11885330
2000			8.2945			2.03952367
2001			9.1721			2.19271756
2002			6.4509			2.28895699
2003			8.8337			4.12208989
2004			8.4901			3.13308117
2005			5.8526			3.65377605
2006			10.431			3.91051113
2007			5.932			2.67305287
2008			3.991			2.39078035
2009			5.349			2.39307184
2010			7.871			3.26066153
2011			5.909			3.40038198
2012			1.570			1.79186429

Table 4. The nominal CPUE and its respective quarterly standardized CPUE of north Atlantic albacore based on the Taiwanese catch statistics from 1967 to 2012.

Year*Quarter	Nominal CPUE 1	Nominal CPUE 2	Nominal CPUE 3	Standardized CPUE 1	Standardized CPUE 2	Standardized CPUE 3
19671						
19672						
19673	21.584			6.01678		
19674	18.616			7.29274		
19681	28.102			13.94572		
19682	13.905			12.41903		
19683	15.997			11.31812		
19684	12.946			10.56351		
19691	26.845			10.86800		
19692	5.615			7.55531		
19693	12.946			10.04902		
19694	16.479			13.87213		
19701	10.768			12.37301		
19702	23.891			9.94332		
19703	10.612			8.33730		
19704	13.166			6.94038		
19711	26.540			8.79982		
19712	8.086			6.52456		
19713	2.988			4.94023		
19714	27.098			7.07915		
19721	37.152			11.49623		
19722	7.999			4.60711		
19723	17.740			5.17358		
19724	28.341			8.88881		
19731	36.039			11.32026		
19732	17.039			6.55140		
19733	19.662			8.60997		
19734	32.923			9.67537		
19741	30.448			9.75236		
19742	22.134			7.32812		
19743	15.352			6.36699		
19744	34.942			9.15618		
19751	24.749			9.36284		
19752	19.028			5.08416		
19753	17.147			4.96428		
19754	51.403			10.04345		
19761	38.377			14.05836		
19762	22.534			9.02322		
19763	12.938			4.55524		
19764	27.395			11.11528		
19771	21.345			8.95591		
19772	28.056			11.60036		
19773	21.691			8.32412		
19774	25.408			8.93907		
19781	29.169			12.25375		
19782	18.102			6.92281		
19783	16.634			7.42504		
19784	25.207			8.55604		
19791	38.319			14.94893		
19792	22.538			7.59835		
19793	14.878			5.01175		
19794	41.811			9.39966		
19801	36.363			13.88855		
19802	23.219			7.52315		
19803	18.737			5.71444		
19804	39.477			9.99415		
19811	32.539			10.12545		
19812	22.497			8.03385		
19813	21.375			7.76968		
19814	34.930			9.25665		
19821	35.980			11.69896		
19822	28.692			9.71161		
19823	24.060			7.17066		
19824	46.096			10.42738		

Year*Quarter	Nominal CPUE 1	Nominal CPUE 2	Nominal CPUE 3	Standardized CPUE 1	Standardized CPUE 2	Standardized CPUE 3
19831	35.024			9.03256		
19832	27.122			9.24771		
19833	25.116			8.61943		
19834	37.325			13.54584		
19841	35.753			11.76553		
19842	24.651			8.33195		
19843	20.882			6.61802		
19844	25.941			7.19847		
19851	26.041			8.95814		
19852	19.003			8.03028		
19853	16.490			4.76867		
19854	26.250			7.99185		
19861	22.698			7.00252		
19862	16.686			5.28879		
19863	16.171			5.61626		
19864	21.492			5.61228		
19871	17.412	17.412		6.09949	4.08011	
19872	14.052	14.052		4.49536	2.84960	
19873	14.304	14.304		6.01996	5.49771	
19874	21.208	21.208		7.18685	4.75798	
19881		31.100			7.55129	
19882		30.404			5.64772	
19883		23.756			8.77528	
19884		24.654			5.82149	
19891		28.175			6.77518	
19892		18.879			3.57549	
19893		19.121			5.07211	
19894		12.921			4.66727	
19901		11.871			5.33737	
19902		5.480			3.57770	
19903		3.396			2.42610	
19904		2.635			3.34958	
19911		5.967			5.31630	
19912		6.927			5.48333	
19913		6.613			3.67241	
19914		4.837			4.95645	
19921		1.808			4.35425	
19922		4.286			4.58233	
19923		6.385			2.95968	
19924		2.220			4.11551	
19931		0.437			2.43936	
19932		14.588			4.14727	
19933		10.340			4.94262	
19934		12.376			3.21040	
19941		7.443			2.64852	
19942		10.784			1.86712	
19943		25.267			3.81850	
19944		11.046			2.82360	
19951		12.647			2.80013	
19952		20.633			2.79974	
19953		24.229			4.52307	
19954		10.046			2.17423	
19961		14.284			2.68223	
19962		4.440			1.84386	
19963		1.790			1.57007	
19964		5.636			1.08111	
19971		11.621			3.35946	
19972		5.788			2.17753	
19973		3.255			1.63207	
19974		8.654			1.81710	
19981		17.234			2.37748	
19982		12.073			1.99694	
19983		12.042			2.19238	
19984		7.285			2.42145	

Year*Quarter	Nominal CPUE 1	Nominal CPUE 2	Nominal CPUE 3	Standardized CPUE 1	Standardized CPUE 2	Standardized CPUE 3
19991		7.465	7.465		3.08764	3.44726
19992		5.844	5.844		1.18847	1.69633
19993		7.142	7.142		1.29292	1.78907
19994		7.237	7.237		1.23985	1.82383
20001			9.363			2.77940
20002			9.427			2.19942
20003			5.129			1.65861
20004			8.414			1.29266
20011			8.778			2.60965
20012			8.679			1.92168
20013			8.784			2.09026
20014			11.908			2.37288
20021			7.716			3.52590
20022			3.895			1.83717
20023			6.901			1.79040
20024			8.072			2.15263
20031			7.568			4.53236
20032			6.853			3.84151
20033			11.789			3.75784
20034			16.170			5.02704
20041			0.111			2.71981
20042			10.140			2.90328
20043			12.562			2.78788
20044			18.159			4.19767
20051			5.687			5.94695
20052			5.694			3.50731
20053			5.465			2.15041
20054			8.287			3.96455
20061			11.988			5.65099
20062			8.199			3.00064
20063			11.526			3.34733
20064			10.725			3.99771
20071			5.893			2.76363
20072			5.634			2.82506
20073			8.154			2.66330
20074			3.715			1.98676
20081			3.252			2.70513
20082			4.284			2.23005
20083			3.415			1.98105
20084			6.896			2.82885
20091			6.381			2.96542
20092			5.209			2.39927
20093			7.163			2.49354
20094			0.417			1.55154
20101			9.586			3.62737
20102			6.358			2.84707
20103			8.239			2.78680
20104			7.044			4.17886
20111			5.729			3.07744
20112			4.732			2.74858
20113			7.064			4.04948
20114			6.267			3.71170
20121			3.345			3.16042
20122			0.201			1.26693
20123			0.004			1.04911
20124			0.646			1.85866

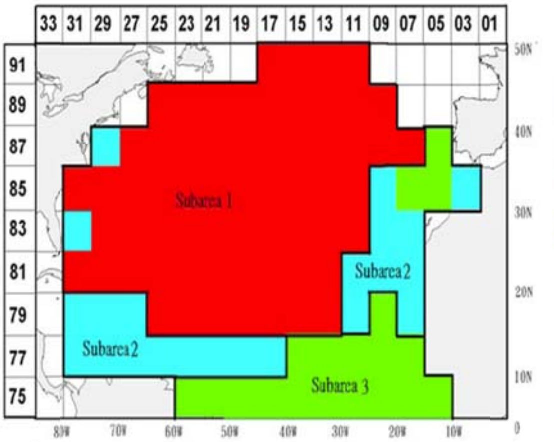

Figure 1. Map showing the segregation of subareas in the GLM analyses of present study.

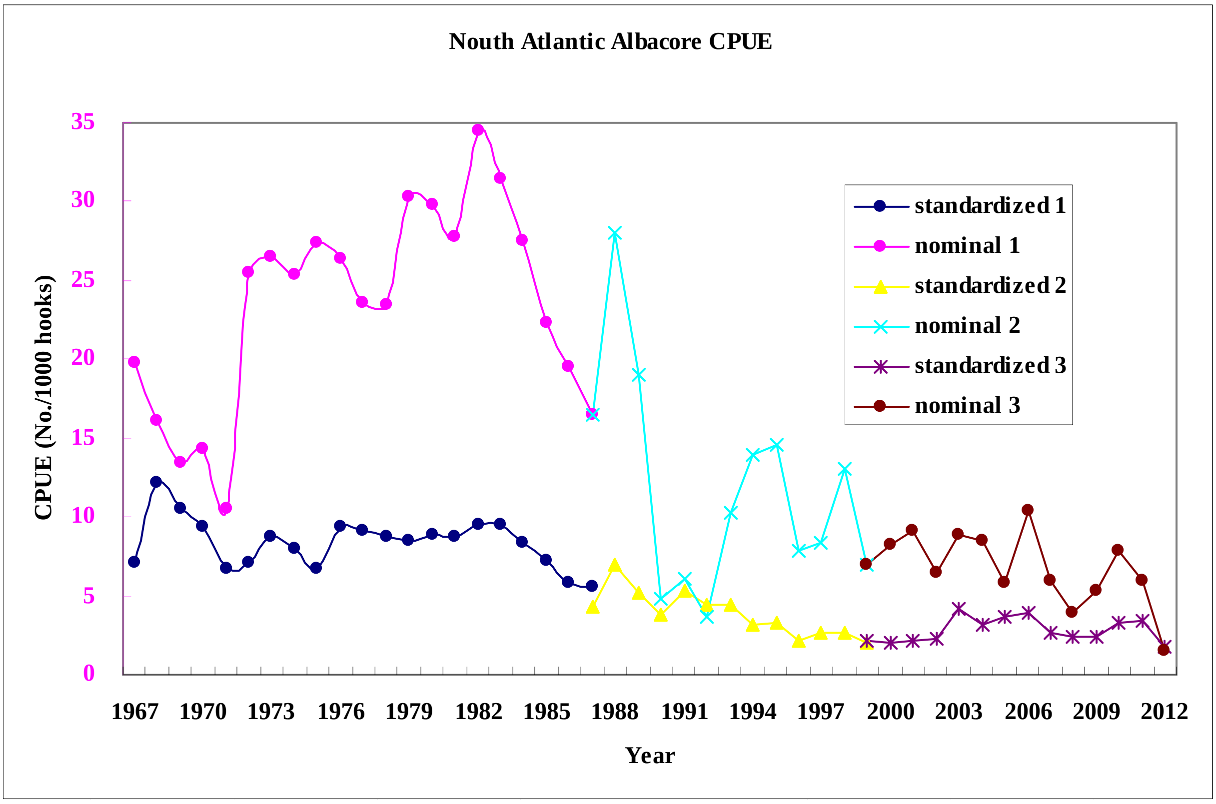

Figure 2. Yearly nominal and standardized CPUE (No/1000 hooks) trends of north Atlantic albacore based on Taiwanese longline fishery data set from 1967 to 2012.

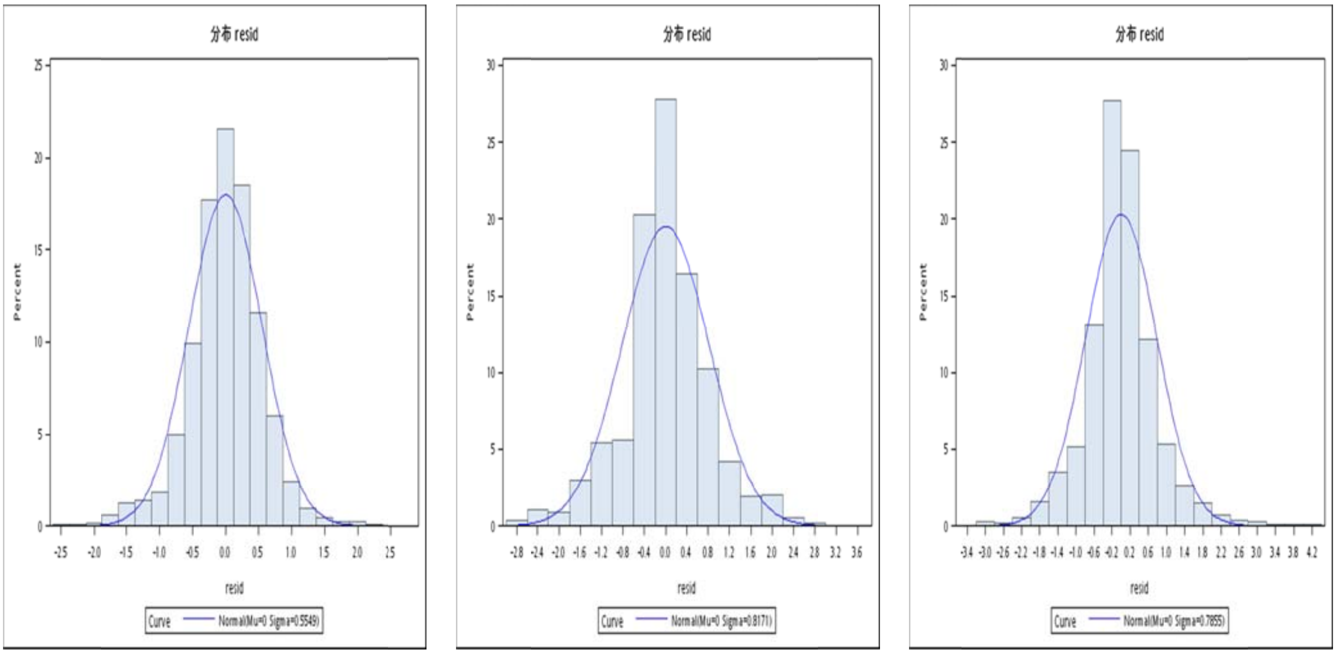

Figure 3. Distribution of normalized residuals obtained from yearly GLM model.

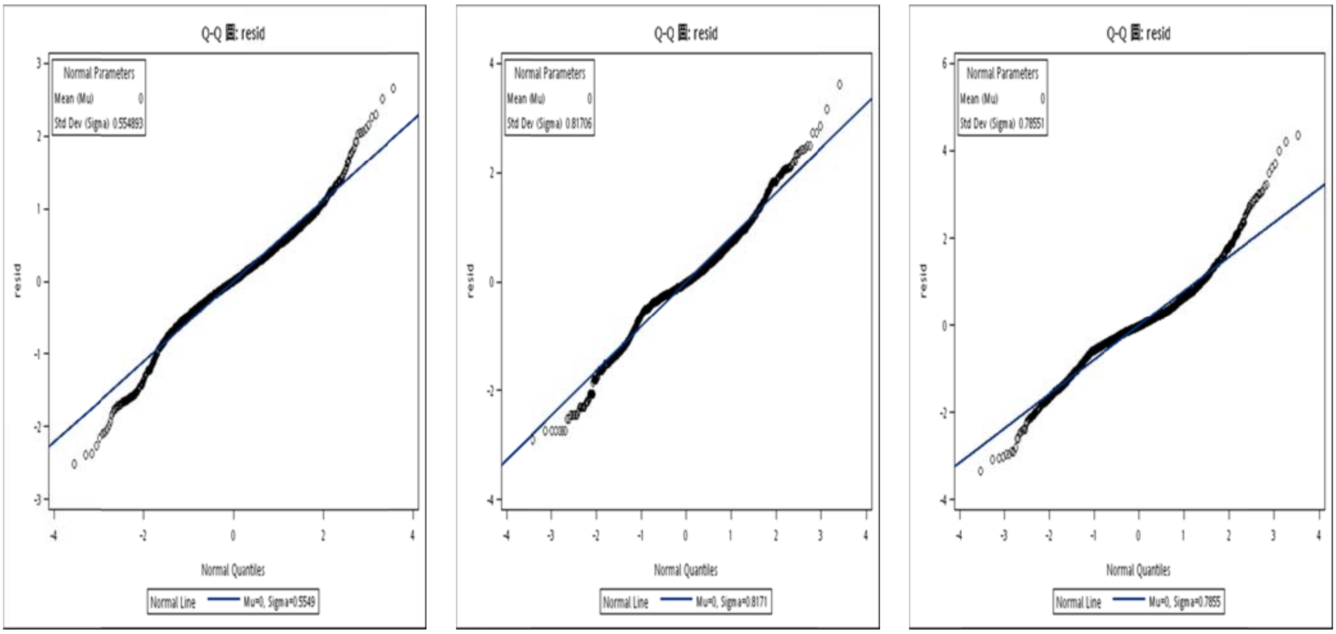

Figure 4. The Q-Q plot for residuals obtained from yearly GLM model.

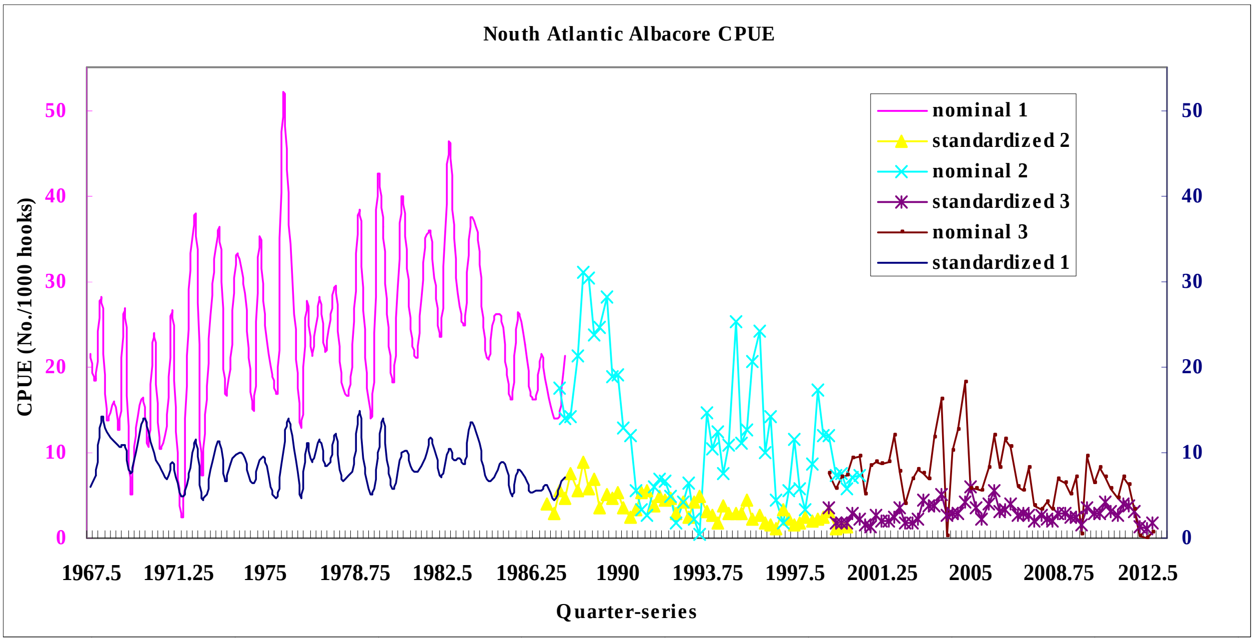

Figure 5. Quarterly nominal and standardized CPUE (No/1000 hooks) trend of north Atlantic albacore based on Taiwanese longline fishery data set from 1967 to 2012.

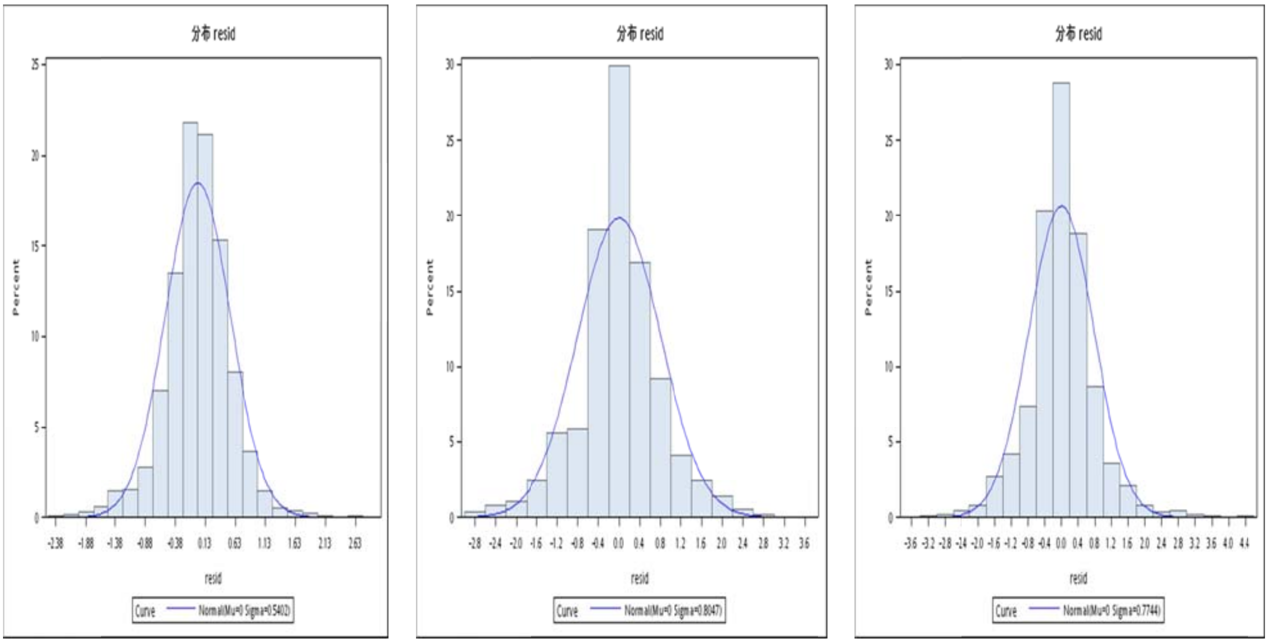

Figure 6. Distribution of normalized residuals obtained from quarterly GLM model.

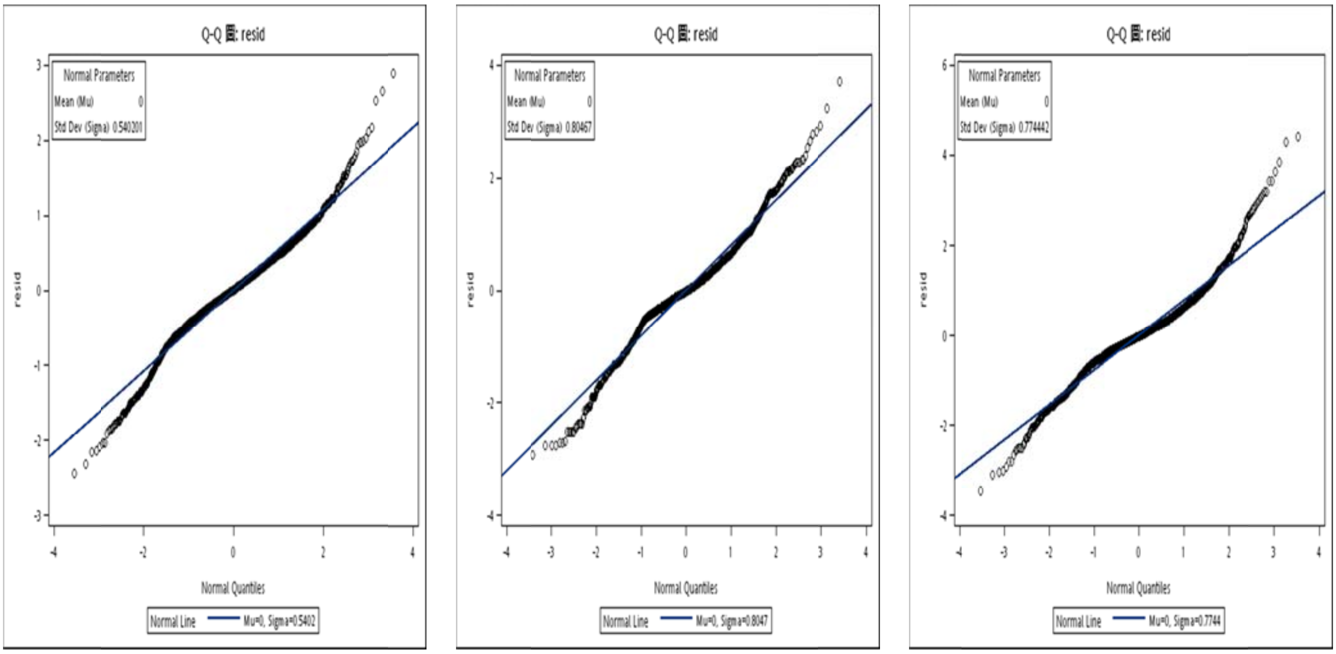

Figure 7. The Q-Q plot for residuals obtained from quarterly GLM model.