STANDARDIZED CPUE OF SOUTH ATLANTIC ALBACORE (*THUNNUS ALALUNGA*) BASED ON TAIWANESE LONGLINE CATCH AND EFFORT STATISTICS DATING FROM 1967 TO 2005

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SUMMARY

Standardized abundance index of South Atlantic albacore, dating from 1967 to 2005, based on Taiwanese longline catch and effort statistics by using Generalized Liner Model (GLM) procedure were carried out in present study. Factors as year, quarter, subarea, by-catch effects of bigeye tuna, yellowfin tuna, and swordfish were used to obtain the yearly standardized CPUE trend from 1967 to 2005. Quarterly standardized CPUE series from the 3rd quarter of 1967 to the 4th quarter of 2005 were also obtained by using quarter-series, subarea, by-catch effects of bigeye tuna, yellowfin tuna, and swordfish as factors of concern. CPUE, both yearly and quarterly, trends thus obtained indicated that the abundance in number of South Atlantic albacore declined from late-1960s to 1990 and leveled off up to 2003 and appeared an upward trend in 2004 and 2005. Quarterly trend, as compared to its respective yearly trend, often appeared a significant peak per year implied a consistent recruitment pattern of this resource.

RÉSUMÉ

La présente étude examine l'indice d'abondance standardisée du germon de l'Atlantique Sud, remontant de 1967 à 2005, sur la base des statistiques de prise et d'effort de la flottille palangrière du Taïpei chinois en ayant recours à la procédure du modèle linéaire généralisé (GLM). Les facteurs tels que année, trimestre, sous-zones, effets de prise accessoire du thon obèse, de l'albacore et de l'espadon ont été utilisés afin d'obtenir la tendance annuelle de la CPUE standardisée de 1967 à 2005. Les séries de CPUE standardisée trimestriellement du 3ème trimestre de 1967 au 4ème trimestre de 2005 ont également été obtenues en utilisant les séries trimestrielles, sous-zone, et prise accessoire du thon obèse, de l'albacore et de l'espadon comme facteurs présentant un intérêt particulier. Les tendances annuelles et trimestrielles de la CPUE ainsi obtenues ont indiqué que l'abondance numérique du germon de l'Atlantique Sud a chuté à partir de la fin des années 1960 jusqu'en 1990, s'est stabilisée jusqu'en 2003, puis a dégagé une tendance ascendante en 2004 et 2005. La tendance trimestrielle, comparée à sa tendance annuelle respective, montre souvent un point culminant considérable tous les ans, ce qui impliquerait un schéma cohérent de recrutement de cette ressource.

RESUMEN

En el presente estudio se calculó el índice de abundancia estandarizado del atún blanco del Atlántico sur, desde 1967 hasta 2005, basado en las estadísticas de captura y esfuerzo del palangre de Taipei Chino utilizando un modelo lineal generalizado (GLM). Se utilizaron factores como año, trimestre, subárea, y efectos de la captura fortuita de patudo, rabil y pez espada para obtener la tendencia anual de la CPUE estandarizada anualmente desde 1967 hasta 2005. La serie de CPUE estandarizada trimestralmente desde el 3er trimestre de 1967 hasta el 4º trimestre de 2005 se obtuvo también utilizando series trimestrales, subárea, y efectos de la captura fortuita de patudo, rabil y pez espada como factores de inquietud. Las tendencias de CPUE, tanto anual como trimestral, obtenidas así indicaron que la abundancia en número del atún blanco del Atlántico sur descendió desde finales de los 60 hasta 1990 y se niveló hasta 2003, apareciendo una tendencia creciente en 2004 y 2005. La tendencia trimestral, comparada con su respectiva tendencia anual, mostraba a menudo un pico importante por año que implicaba un patrón de reclutamiento coherente de este recurso.

KEYWORDS

Albacore, abundance index, longline, by-catch

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1. Introduction

In the Atlantic Ocean, two stocks of albacore, separated by 5° N latitude, were assumed for the fishery management. Taiwanese longline fishery, followed Japanese footstep, has become one of the major fishing fleets utilizing this resource since 1960s. According to the ICCAT report, annual catch of South Atlantic albacore ranged from 25,000 mt to 35,000 mt in the last decade. Taiwanese catch of South Atlantic albacore comprised of 70% or more of the total. As one of the fishing nations that utilized this resource, it is equally our responsibility to acquire the catch and effort statistics for the purpose of monitoring its status.

Taiwanese longliners in the Atlantic composed mainly of two types of fishing gears, i.e., regular longliner and deep longliner. The regular longliner, which commenced since 1960s and is also called traditional longliner, is mainly targeting on albacore. Since mid-1980s, another type of lonliner or so called deep longliner, which equipped with –70 degree centigrade or more freezing capability, emerged and mainly targeting on bigeye and yellowfin tunas. Unfortunately, it was not until mid-1990s when the logbook reporting system was able to distinguish their major identity by the addition of "the number of hooks per basket used" in new reporting logbook. Nevertheless, historic task2 data series compiled by Taiwanese Fisheries Managerial Sector and reported to the ICCAT since late-1960s thus become one of the important data sources to investigate the long-term abundance fluctuation of this resource.

The main purposes of this study were thus to standardize the South Atlantic albacore abundance indices, based on Taiwanese 1967-2005 task2 data series, by using Generalized Linear Models with identifiable factors as year, quarter, fishing locations, by-catch information for the purpose of minimizing the aforementioned incompatibility may have aroused in the data set, which were collected over a rather vast area-time-fishery spectra.

2. Materials and methods

The task2 data, aggregated by month and by 5° statistical block from 1967 to 2005, were compiled and provided by Overseas Fisheries Development Council of Taiwan. Nominal CPUE was defined as catch in number per 1,000 hooks.

Although the Atlantic water mass is generally considered having the North Atlantic mid-ocean gyre and South Atlantic mid-ocean gyre, the delineation of North Atlantic albacore from South Atlantic albacore was set at 5° N latitude. Furthermore, the habitat of South Atlantic albacore is currently designated and separated from the Indian Ocean by the 20° E longitude. As of the entire habitat for South Atlantic albacore, it is thus designated currently as from 5° N southward and set 20° E as its eastward boundary condition.

GLM with normal error structure (Robson, 1966; Gavaris, 1980; Kimura, 1981) was used in present study to standardize yearly and quarterly CPUE series of the South Atlantic albacore. Factors used in the yearly standardization are year, quarter, subarea, effects of by-catch, which includes bigeye tuna, yellowfin tuna and swordfish. Factors used in the quarterly standardization, however, are quarter-series, subarea, effects of by-catch, which includes bigeye tuna, yellowfin tuna and swordfish. The nominal CPUE values of those by-catch species were calculated and coded by quantile. GLM models constructed in present study for yearly and quarterly standardizations are as follows:

2.1 Yearly generalized linear model with normal error structure:

$$LOG(CPUE_{ijklmn}+const)=\mu+YEAR_i+QUARTER_j+SUBAREA_k+CODEBET_l+CODEYFT_m+CODESWO_n+\xi_{ijklmn}$$

where
LOG: natural logarithm;
$CPUE_{ijklmn}$: nominal albacore CPUE (catch in number per 1000 hooks) in year *i*, quarter *j*, subarea *k*, and bycatch of BET_l, YFT_m, SWO_n,
μ: intercept, or overall mean for correction;
const: constant (10% of the overall mean albacore nominal CPUE);
$YEAR_i$: main effect of year *i*;
$QUARTER_j$: effect of quarter *j*;
$SUBAREA_k$: effect of subarea *k*;

$CODEBET_l$: effect of bycatch (bigeye tuna);
$CODEYFT_m$: effect of bycatch (yellowfin tuna);
$CODESWO_n$:effect of bycatch (sword fish);
$\xi_{ijkl\ mn}$: lack of fit (error) with distribution character of $N(0,\sigma^2)$.

2.2 Quarterly generalized linear model with normal error structure:

$$LOG(CPUE_{iklmn}+const)=\mu+QUARTER\text{-}SERIES_i+SUBAREA_k+CODEBET_l+CODEYFT_m+CODESWO_n+\xi_{iklmn}$$

where
LOG: natural logarithm;
$CPUE_{iklmn}$: nominal albacore CPUE (catch in number per 1000 hooks) in quarter-series i, subarea k, and by-catch of BET_l, YFT_m, SWO_n,
μ: intercept, or overall mean for correction;
const: constant (10% of the overall mean albacore nominal CPUE);
$QUARTER\text{-}SERIES_i$: main effect of quarter-series i;
$SUBAREA_k$: effect of subarea k;
$CODEBET_l$: effect of bycatch (bigeye tuna);
$CODEYFT_m$: effect of bycatch (yellowfin tuna);
$CODESWO_n$:effect of bycatch (sword fish);
$\xi ikl\ mn$: lack of fit (error) with distribution character of $N(0,\sigma^2)$.

SAS Ver. 9.1.3. statistical package was used in both cases to obtain solutions.

3. Results and discussion

A constant 1.72, which was obtained by averaging all Taiwanese longliners' nominal albacore CPUE reported from 1967 to 2005 in the South Atlantic and divided 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).

For elucidating geographical distribution characters of South Atlantic albacore resource, an aggregated (from 1967 to 2005) geographic distribution map of nominal albacore CPUE in number was shown in **Figure 1**. As shown in **Figure 1**, significant area aggregation with different level of catch rate was observed. In particular, an aggregation with higher catch rate appeared between 10°S and 45°S of the South Atlantic. The same pattern was also observed in **Figure 2**, which is obtained exactly the same procedure used to obtain **Figure 1** but using nominal albacore CPUE in weight instead of number. To divide appropriately the South Atlantic albacore's entire habitat into subareas is one of the attempts used in present study for providing corrections stemmed from area contrast. Three subareas, as shown in **Figure 3**, were thus used in present study followed the resultant obtained by Wu and Yeh (2002).

The ANOVA tables, as shown in **Table 1** and **2**, which were provided by SAS solver, indicated that (1) factors assigned both in yearly model and in quarter-series model are statistically significant; (2) factor subarea plays an important role in explanation of its orthogonal variation to the total; (3) comparatively, factor by-catch of yellow fin tuna played a less significant role as its mean square is relatively low, although still significant; (4) the determination coefficient r-square approached 80% in both cases indicated the explanatory resultant by the two models are quite significant.

The nominal yearly CPUE trend and its respective standardized yearly CPUE series thus obtained were tabulated in **Table 3**, and plotted in **Figure 4**. The standardized yearly CPUE series showed a continuous decline from late-1960s to 1990 and leveled off up to 2003, and appeared an upward trend in 2004 and 2005. The normalized residual pattern from this model is shown in **Figure 5**. As shown in **Figure 5**, main distribution of residuals ranged from –1.65 to +1.65 and obviously centered at zero as mode. Q-Q plot of those residuals were also shown in **Figure 6** indicating the fitting is generally good.

The nominal quarterly CPUE trend and its respective standardized quarterly CPUE series thus obtained were tabulated in **Table 4**, and plotted in **Figure 7**. The standardized quarterly CPUE series showed a continuous decline from late-1960s to 1990s with higher fluctuation and leveled off up to 2003 and appeared an upward trend in 2004 and 2005. The general trend appeared in quarterly CPUE series is very similar with those obtained in yearly CPUE trend. Although quarterly trend having more fluctuations, it is very interesting to point out that

every four quarters always appeared a high peak strongly implies that a consistent recruitment may have coming in every year. The normalized residual pattern from this model is shown in **Figure 8**. As shown in **Figure 8**, main distribution of residuals also ranged from –1.65 to +1.65 and obviously centered at zero as mode. Q-Q plot of those residuals were shown in **Figure 9** indicating the fitting is generally good.

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Table 1. Analysis of variance on standardizing South Atlantic albacore yearly CPUE using Taiwanese longline fishery data set from 1967 to 2005 by GLM procedure.

Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	52	15536.25312	298.7741	859.48	<.0001
Error	12593	4377.60754	0.34762		
Corrected Total	12645	19913.86066			

R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean
0.780173	25.32564	0.589595	2.328056

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	38	972.238012	25.585211	73.6	<.0001
quarter	3	47.539984	15.846661	45.59	<.0001
subarea	2	3712.216652	1856.108326	5339.44	<.0001
codebet	3	350.905317	116.968439	336.48	<.0001
codeyft	3	21.978474	7.326158	21.08	<.0001
codeswo	3	107.149658	35.716553	102.75	<.0001

Table 2. Analysis of variance of standardized South Atlantic albacore quarterly CPUE using Taiwanese longline fishery data set from 1967 to 2005 by GLM procedure.

Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	164	15721.66158	95.86379	285.41	<.0001
Error	12481	4192.19908	0.33589		
Corrected Total	12645	19913.86066			

R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean
0.789483	24.89447	0.579557	2.328056

Source	DF	Type III SS	Mean Square	F Value	Pr > F
quarter-series	153	1170.995187	7.653563	22.79	<.0001
subarea	2	3392.476272	1696.238136	5050.03	<.0001
codebet	3	365.724849	121.908283	362.94	<.0001
codeyft	3	17.847526	5.949175	17.71	<.0001
codeswo	3	100.869425	33.623142	100.1	<.0001

Table 3. Yearly nominal and standardized CPUE trends of South Atlantic albacore based on Taiwanese longline fishery data set from 1967-2005 using GLM procedure.

Year	Nominal CPUE	Standardized CPUE
1967	42.5397	20.73676
1968	36.4662	18.49407
1969	31.9235	19.72115
1970	32.0003	14.79915
1971	34.7891	14.90132
1972	29.4183	10.34024
1973	26.5663	9.01642
1974	27.8128	10.19139
1975	33.3248	11.90575
1976	29.3413	12.59592
1977	34.645	13.75206
1978	35.6167	12.27982
1979	31.7251	11.42543
1980	32.5274	10.50621
1981	28.1104	8.38456
1982	29.4014	8.39341
1983	28.5808	8.22829
1984	29.3737	9.29125
1985	30.1249	8.88115
1986	32.0127	8.78391
1987	24.4444	7.76407
1988	19.7463	5.60048
1989	16.9744	5.04660
1990	17.5267	5.23672
1991	13.382	6.05516
1992	15.9749	7.19445
1993	15.4734	6.12555
1994	19.5675	7.78974
1995	14.8522	7.74512
1996	14.149	8.16739
1997	14.2832	7.67431
1998	9.5317	6.66396
1999	9.069	5.55012
2000	8.9644	5.10430
2001	11.746	6.17754
2002	8.3779	5.00067
2003	8.0086	4.64416
2004	9.6431	6.72050
2005	10.2007	5.95260

Table 4. Quarterly nominal and standardized CPUE trends of South Atlantic albacore based on Taiwanese longline fishery data set from 1967-2005 by GLM procedure.

Quarter-series	Nominal CPUE	Standardized CPUE
19673	68.353	34.71618
19674	11.266	13.40444
19681	4.489	12.17271
19682	70.526	27.02199
19683	61.763	37.62654
19684	8.249	11.40305
19691	17.980	15.70753
19692	35.011	15.69707
19693	47.495	22.49875
19694	31.342	24.46451
19701	20.079	14.56191
19702	48.468	14.38993
19703	46.473	19.75039
19704	20.592	11.67497
19711	13.561	12.70505
19712	46.982	16.97385
19713	61.003	23.05331
19714	17.875	11.53747
19721	23.308	11.41122
19722	38.736	11.12681
19723	38.530	11.52937
19724	11.061	8.30767
19731	24.393	6.98943
19732	32.566	15.27458
19733	32.847	11.43826
19734	14.319	6.30381
19741	17.342	7.76296
19742	38.741	11.51054
19743	37.585	13.20406
19744	15.594	9.25762
19751	21.911	11.45039
19752	51.520	15.51271
19753	35.749	13.56622
19754	18.024	8.60524
19761	26.671	10.12502
19762	39.089	16.69594
19763	31.752	16.78653
19764	16.061	8.79951
19771	30.440	12.69973
19772	44.278	17.77748
19773	35.682	15.13395
19774	21.555	11.25240
19781	30.446	10.94261
19782	43.472	13.97422
19783	36.225	12.43526
19784	25.144	13.16768
19791	29.922	11.08881
19792	39.043	11.86572
19793	30.026	11.71538
19794	22.781	11.55698
19801	33.655	10.51780
19802	44.678	13.37325
19803	29.136	9.91509
19804	22.174	9.81655
19811	28.466	8.01899
19812	38.385	11.05902
19813	29.698	8.57012
19814	15.693	6.84409
19821	28.896	10.30874
19822	40.803	10.45996
19823	25.594	8.08593
19824	14.240	4.86990
19831	24.430	7.08210
19832	37.101	9.71568
19833	30.967	9.59514
19834	18.590	8.31856
19841	25.264	9.55829
19842	49.841	14.47889
19843	29.871	8.59443
19844	18.074	6.88658
19851	28.009	8.39333
19852	39.675	12.45699
19853	31.700	8.96779
19854	15.578	7.00230
19861	31.901	8.89300
19862	41.899	10.72741
19863	29.878	9.58956
19864	15.020	6.46425
19871	25.893	7.69165
19872	30.187	9.37290
19873	21.775	7.52718
19874	14.340	6.90147
19881	17.214	4.47844
19882	24.004	7.80270
19883	18.351	5.93593
19884	16.528	7.95892
19891	16.913	4.97064
19892	21.058	4.69725
19893	19.304	6.95189
19894	10.358	4.24318
19901	11.075	5.32824
19902	23.914	6.46811
19903	18.303	5.27879
19904	11.531	3.42847
19911	13.081	6.02892
19912	14.872	4.95461
19913	12.672	6.77192
19914	12.771	6.84377
19921	13.226	6.42226
19922	20.959	9.22917
19923	16.796	8.10561
19924	10.251	4.97326
19931	14.654	3.00361
19932	23.880	9.29776
19933	18.514	7.03797
19934	11.129	5.60007
19941	19.558	8.31222
19942	28.825	8.53816
19943	16.381	8.02798
19944	8.029	6.47005
19951	10.864	7.85318
19952	26.619	9.38890
19953	14.626	7.10863
19954	10.311	7.31968
19961	14.743	8.03708
19962	20.881	8.70119
19963	14.358	8.28435
19964	7.353	7.67047
19971	10.606	7.87349
19972	22.372	7.79329
19973	14.563	7.99063
19974	9.204	6.99183
19981	5.685	6.75919
19982	16.640	7.45443
19983	14.234	7.06008
19984	3.585	5.47163
19991	5.850	4.98059
19992	14.094	5.32790
19993	11.268	6.16321
19994	5.317	5.59073
20001	5.837	4.92711
20002	13.199	5.10043
20003	9.961	5.46995
20004	7.221	4.95362
20011	9.186	6.90900
20012	13.908	5.52443
20013	16.797	6.59070
20014	7.779	5.39437
20021	7.179	5.83203
20022	10.126	4.64395
20023	9.225	4.80349
20024	6.529	4.98320
20031	6.665	5.26165
20032	13.948	4.83608
20033	7.943	4.65579
20034	3.758	3.66632
20041	8.276	7.20647
20042	13.624	6.51316
20043	12.967	6.48136
20044	4.910	6.35150
20051	9.393	6.16129
20052	16.872	5.87813
20053	2.885	5.06034
20054	0.320	6.90471

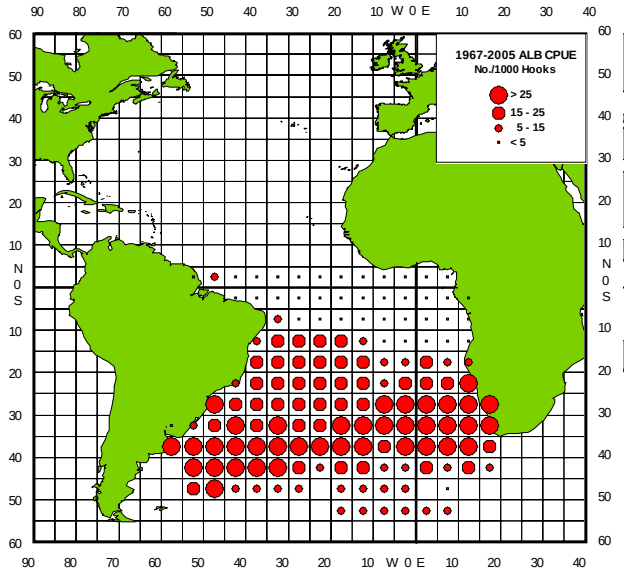

Figure 1. Geographic distribution of South Atlantic albacore nominal CPUE (No./1000 Hooks) based on Taiwanese longline fishery data set from 1967 to 2005.

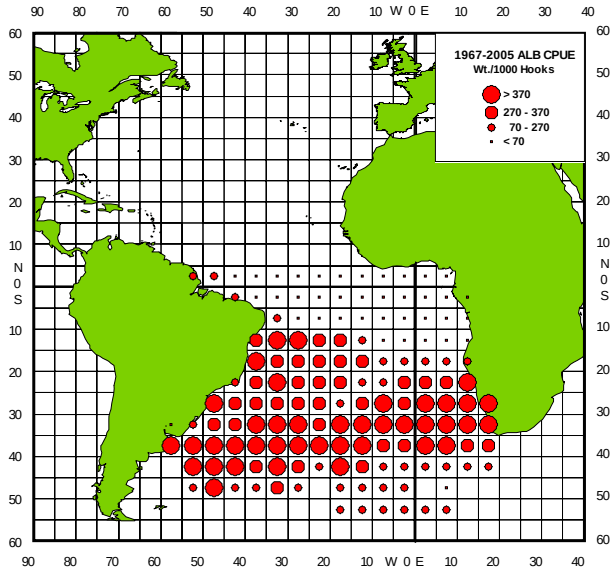

Figure 2. Geographic distribution of South Atlantic albacore nominal CPUE (Wt./1000 Hooks) based on Taiwanese longline fishery data set from 1967 to 2005.

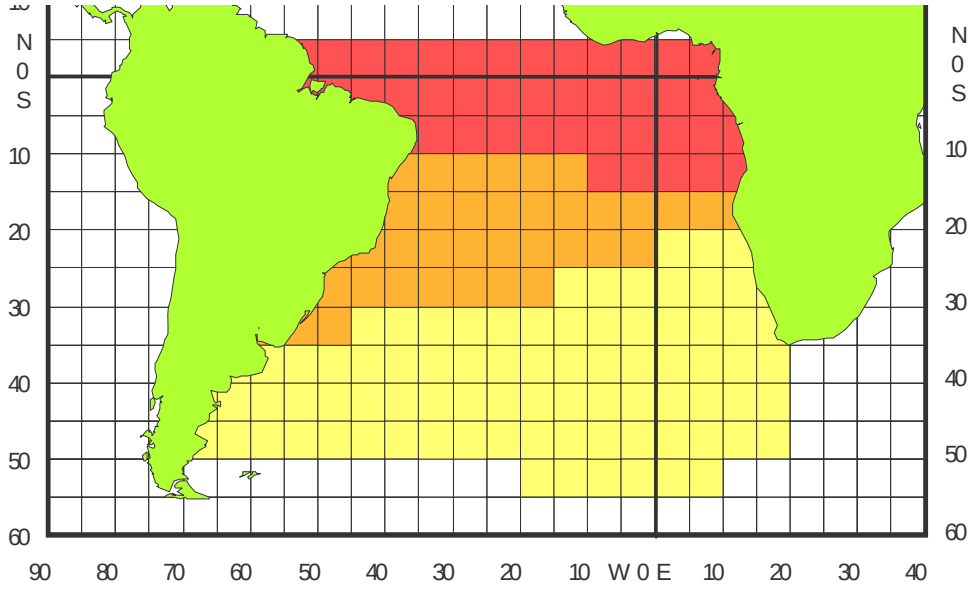

Figure 3. Subarea delineation for South Atlantic albacore habitat.

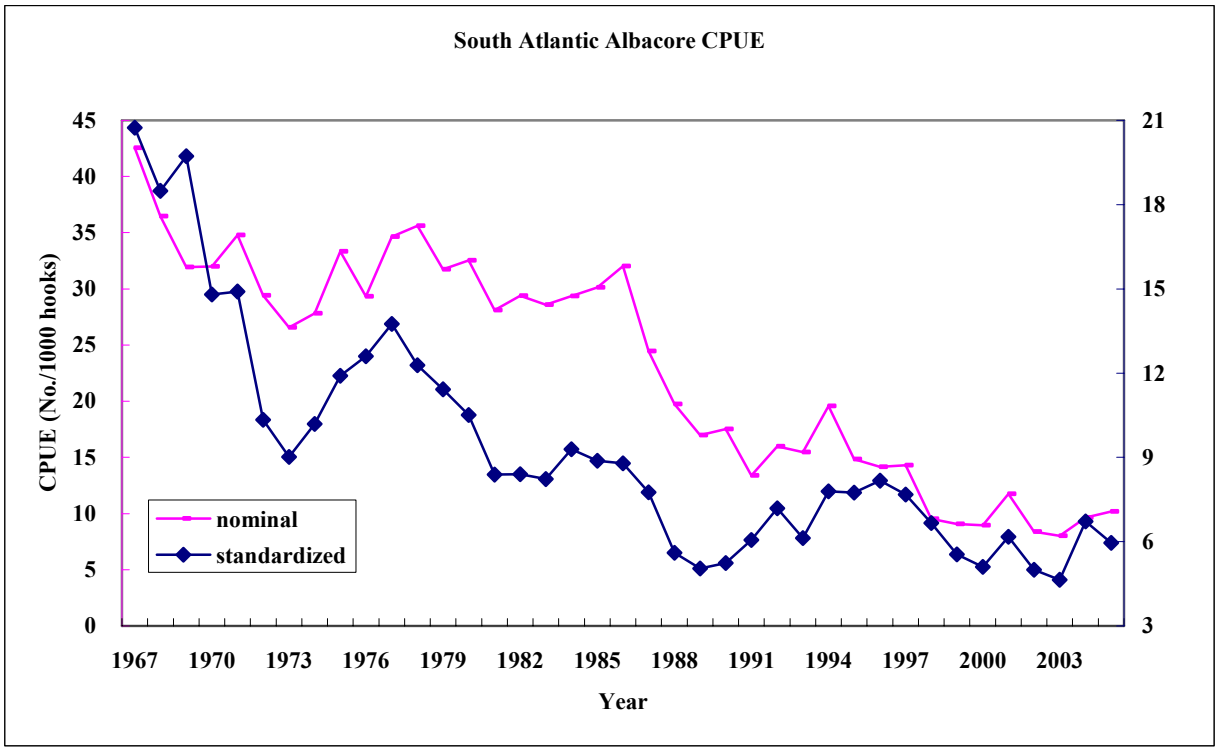

Figure 4. Yearly nominal and standardized CPUE (No/1000Hooks) trends of South Atlantic albacore based on Taiwanese longline fishery data set from 1967 to 2005.

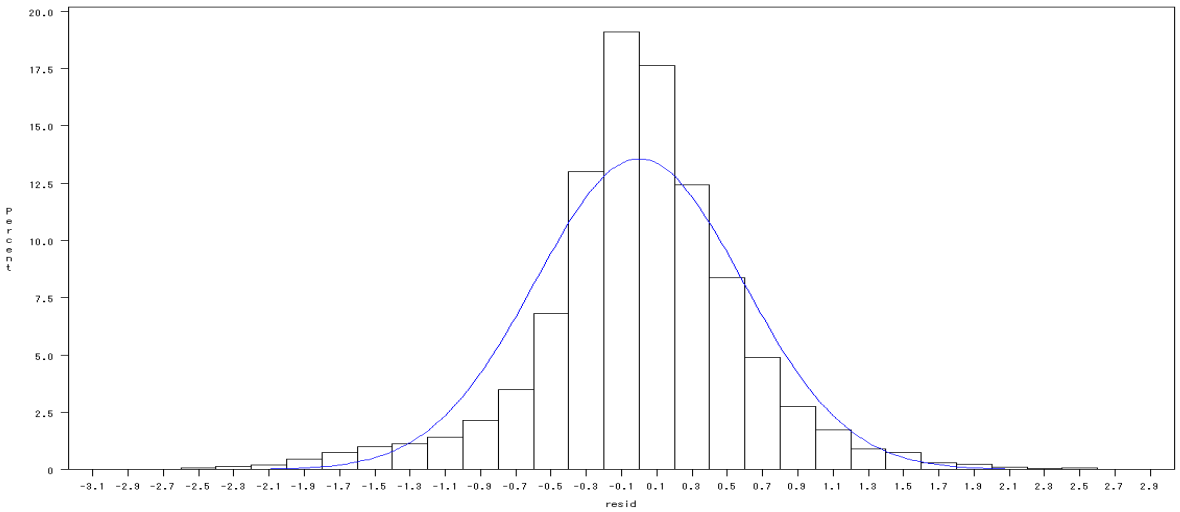

Figure 5. Distribution of normalized residual obtained from yearly GLM model.

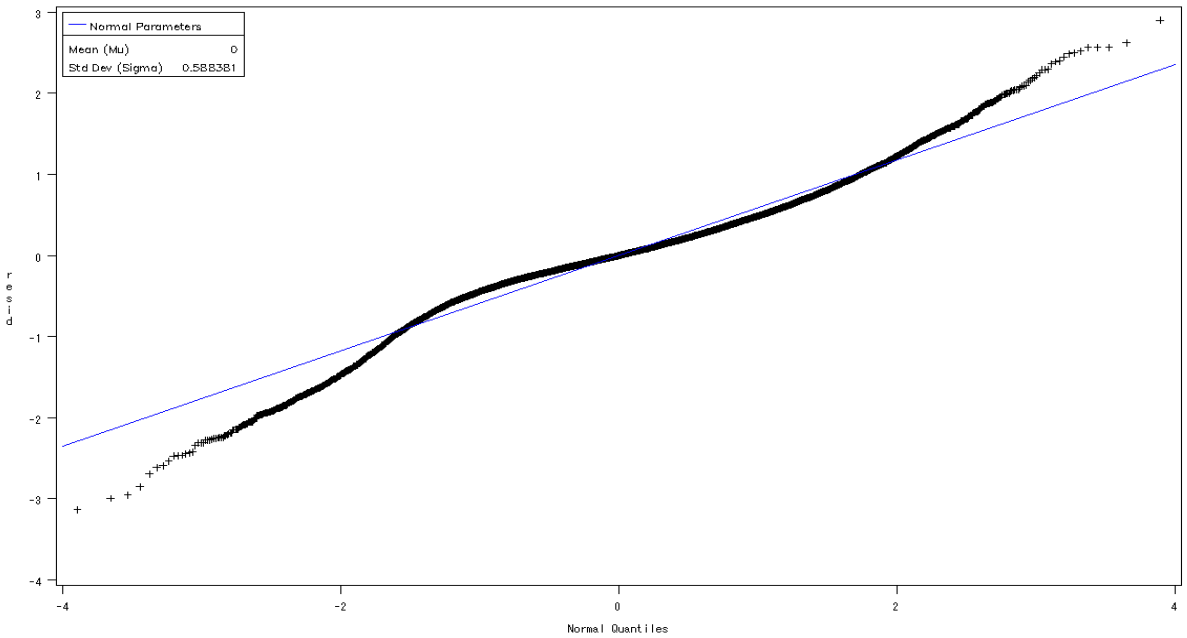

Figure 6. The Q-Q plot for residuals obtained from yearly GLM model.

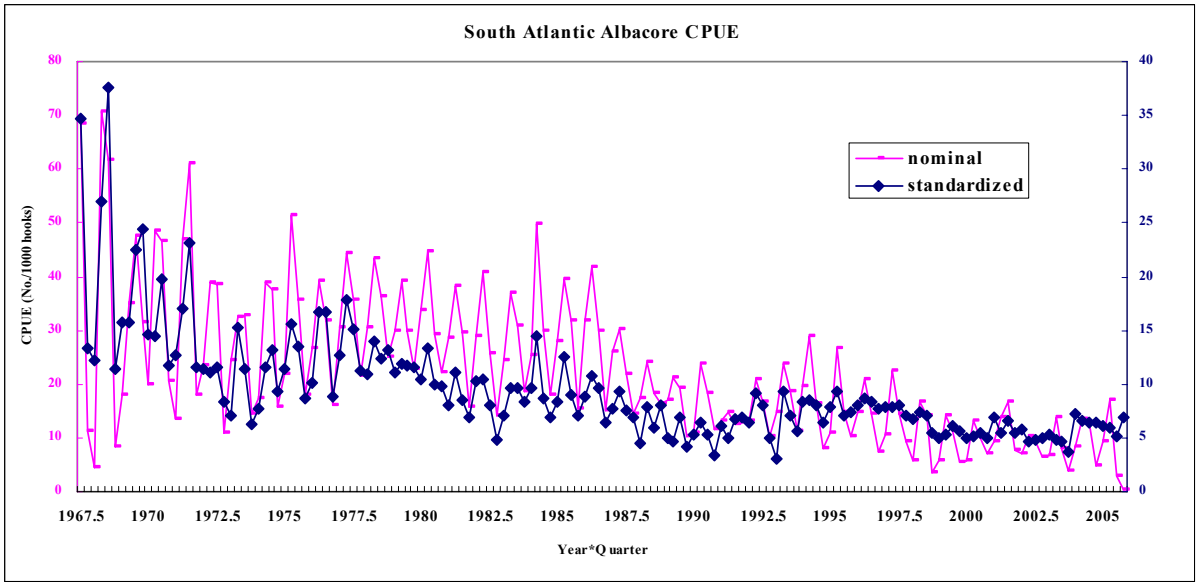

Figure 7. Quarterly nominal and standardized CPUE (No./1000Hooks) trends of South Atlantic albacore based on Taiwanese longline fishery data set from 1967 to 2005.

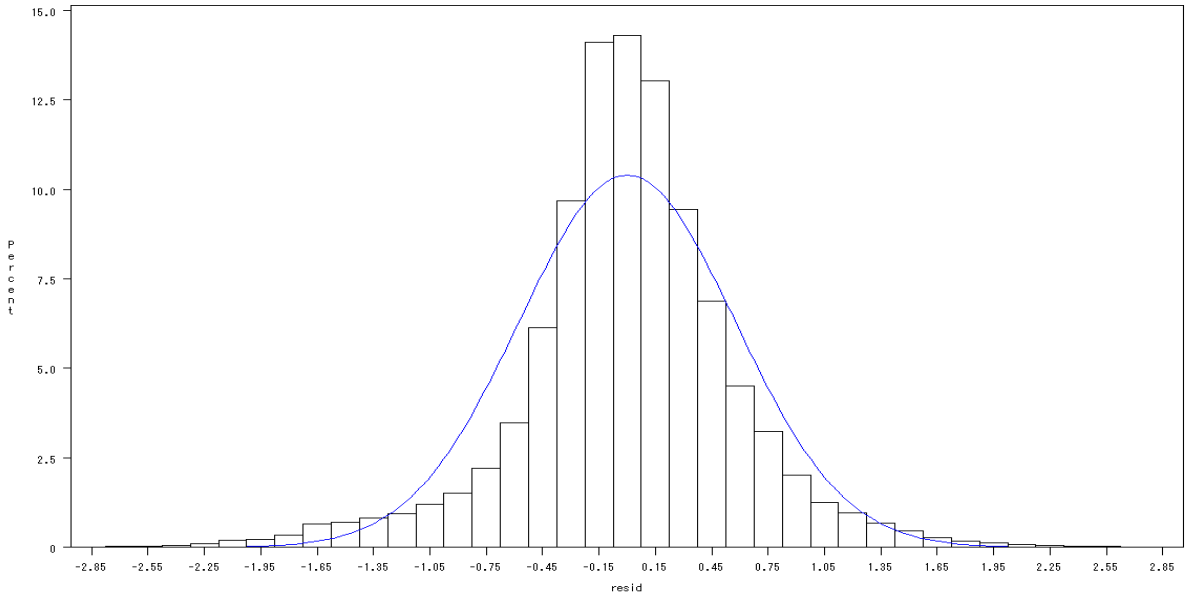

Figure 8. Distribution of normalized residual obtained from quarterly GLM model.

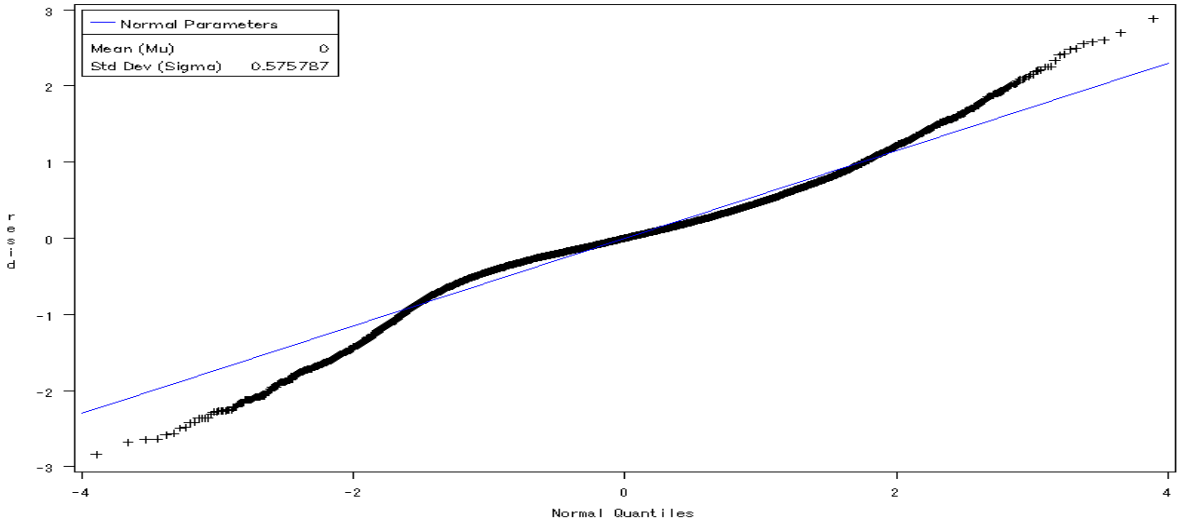

Figure 9. The Q-Q plot for residuals obtained from quarterly GLM model.