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Standardized CPUE of Indian albacore (Thunnus alalunga) based on Taiwanese longline catch and effort statistics dating from 1980 to 2006

Feng-Chen Chang[1], Chiee-Young Chen[2] and Shean-Ya Yeh[3]

SUMMARY

Standardized abundance index of Indian albacore, dating from 1980 to 2006, 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, bycatch effects of bigeye tuna, yellowfin tuna, and swordfish were used to obtain the standardized yearly CPUE trend from 1980 to 2006. Standardized quarterly CPUE series from the 1st quarter of 1980 to the 4th quarter of 2006 were also obtained by using quarter-series, subarea, bycatch effects of bigeye tuna, yellowfin tuna, and swordfish as factors of concern.

Yearly CPUE trend of Indian albacore thus obtained indicated that it appeared a decline trend from early 1980 to late 1980 and leveled off since early 1990 upto mid 2004. In the past two years, however, a moderate decline in CPUE was observed in correspondence with a significant reduction of traditional Taiwanese albacore targeting longline fishery. Quarterly CPUE trend showed a similar trend as those of yearly fluctuations. Incidentally, a periodic ups and down in CPUE index was also notified as a cycle of about ten years. Late 2000 appeared to be along with the downward trend of a cycle.

1 Overseas Fisheries Development Council, Taipei, Taiwan; E-mail: fengchen@ofdc.org.tw; d93241008@ntu.edu.tw;
2 National Kaohsiung Marine University, Kaoshiung, Taiwan; E-mail: chency@mail.nkmu.edu.tw;
3 Institute of Oceanography, National Taiwan University, Taipei, Taiwan; E-mail: sheanya@ntu.edu.tw

INTRODUCTION

In the Indian Ocean, albacore is one of the main target species of commercial tuna fishery and has a long history of scientific research. Albacore in the Indian Ocean has, for the last four decades, been mainly exploited by Taiwan, Japan, and Korea. Taiwanese catch of Indian albacore fluctuated mainly between 5,000 mt to 26,000 mt, comprising about 60% of the total Indian albacore catch by all fishing countries. As one of the fishing nations which 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 Indian 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 IOTC thus became 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 Indian albacore abundance indices, based on Taiwanese 1980-2006 task2 data series, by using Generalized Linear Models with identifiable factors as year, quarter, fishing locations, bycatch 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.

MATERIALS AND METHODS

The task2 data, aggregated by month and by 5° statistical block from 1980 to 2006, were compiled and provided by Overseas Fisheries Development Council of Taiwan. Nominal CPUE was defined as catch in number per 1,000 hooks.

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 Indian albacore. Factors used in the yearly standardization are year, quarter, subarea, effects of bycatch, which includes bigeye tuna, yellowfin tuna and swordfish. Factors used in the quarterly standardization, however, are quarter-series, subarea, effects of bycatch, which includes bigeye tuna, yellowfin tuna and swordfish. Nominal CPUE values of those bycatch species were calculated and coded by quantile. GLM models constructed in present study for yearly and quarterly standardizations are as follows:

Yearly generalized linear model with normal error structure:

$$\mathbf{LOG(CPUE}_{ijklmn}\mathbf{+const)=\mu+YEAR}_i\mathbf{+QUARTER}_j\mathbf{+SUBAREA}_k\mathbf{+CODEBET}_l\mathbf{+CODEYFT}_m\mathbf{+CODESWO}_n\mathbf{+}\xi_{ijklmn}$$

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 (swordfish);
$\xi_{ijkl\,mn}$: lack of fit (error) with distribution character of $N(0,\sigma^2)$.

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 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);
$QUARTER\text{-}SERIES_i$: 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 (swordfish);
$\xi_{ikl\,mn}$: 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.

RESULTS AND DISCUSSION

A constant of 1.324, which was obtained by averaging all Taiwanese longliners' nominal albacore CPUE reported from 1980 to 2006 in the Indian and divided by 10, was determined and added to each nominal albacore CPUE for the purpose of avoiding zero albacore catch rate problem (ICCAT, 1996).

Nominal abundance of bigeye tuna, yellowfin tuna and swordfish will also be included as factors of bycatch into the model and the value input is using discrete quantile level. The discrete quantile values used for grouping nominal CPUEs were: (1) 0~0.570335, 0.570335~2.38691, 2.38691~5.14787, and greater than 5.14787 for bigeye tuna; (2) 0~0.372567, 0.372567~1.261, 1.261~2.9622, and greater than 2.9622 for yellowfin tuna; and (3) 0~0.0613238, 0.0613238~0.263751, 0.263751~0.621319, and greater than 0.621319 for swordfish, accordingly.

For elucidating geographical distribution characters of Indian albacore resource, an aggregated (from 1980 to 2006) geographic distribution map of nominal albacore CPUE in number was shown in Fig. 1. As shown in Fig. 1, significant area aggregation with different level of catch rate was observed. In particular, an aggregation with higher catch rate appeared in the zonation of from 10°S to 45°S of the Indian Ocean. The same pattern was also observed in Fig. 2, which is obtained using the same procedure yet to replace nominal albacore CPUE in number elements by that of in weight. Based on obtained distribution pattern, an intention was also made here to appropriately delineate the entire

Indian Ocean into subareas, hopefully in accordance with the habitat linkages of albacore. The results thus obtained are shown in Fig. 3.

The ANOVA tables, as shown in Table 1 and 2, which were obtained 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 quarter played a less significant role as its mean square is relatively low, although still significant; (4) the determination coefficient R-square approached 70% 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 Fig. 4. The standardized yearly CPUE series showed a decline trend from early 1980 to late 1980 and leveled off upto 2004. In the past two years, however, a moderate decline was observed in accordance with a sharp decline in traditional albacore targeting fishing activities. The normalized residual pattern from this model is shown in Fig. 5. As shown in Fig. 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 Fig. 6 indicating the abnormality was very mild thus the fitting is good.

The nominal quarterly CPUE trend and its respective standardized quarterly CPUE series thus obtained were tabulated in Table 4, and plotted in Fig. 7. The standardized quarterly CPUE series showed a similar trend as those of obtained in the yearly trend. Although quarterly trend having more fluctuations, it is very interesting to point out that every four quarters always appeared a high peak every four seasons thus strongly implies that recruitment may always incoming every year. The normalized residual pattern from this model is shown in Fig. 8. As shown in Fig. 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 Fig. 9 indicating the fitting was generally good.

Fishing intention maybe well acknowledged through notification on number of hooks per basket. It is very unfortunate that the information on noting of using number of hooks per basket only available since 1995, when a new format of including number of hooks per basket was established and delivered for Taiwanese longliners. Log books recovered in the period of mid 1980 to mid 1990, in particular, herhaps be entangled with mixed fishing intentions yet not able to clarify its identity only through area-time factors thus may produce a biased CPUE trends. Efforts will be devoted to obtain suitable discriminant functions obtained from known fishing intention data set (1995 upward data set) and extrapolating into former entangled period. We hope, through such manupulations, will give a more persuasive resultsant CPUE trend than current endeavours.

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Table 1. Analysis of variance on standardizing Indian albacore yearly CPUE using Taiwanese longline fishery data set from 1980 to 2006 by GLM procedure.

Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	40	18439.29097	460.98227	1031.42	<.0001
Error	18128	8102.08976	0.44694		
Corrected Total	18168	26541.38073			

R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean
0.694737	53.05841	0.668534	1.259997

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	26	638.027416	24.539516	54.91	<.0001
quarter	3	33.383513	11.127838	24.90	<.0001
subarea	2	4654.477871	2327.238935	5207.07	<.0001
codebet	3	280.067682	93.355894	208.88	<.0001
codeyft	3	391.088401	130.36280	291.68	<.0001
codeswo	3	181.317964	60.439321	135.23	<.0001

Table 2. Analysis of variance of standardized Indian albacore quarterly CPUE using Taiwanese longline fishery data set from 1980 to 2006 by GLM procedure.

Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	118	18616.88539	157.77022	359.36	<.0001
Error	18050	7924.49535	0.43903		
Corrected Total	18168	26541.38073			

R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean
0.701429	52.58693	0.662594	1.259997

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yq	107	849.093398	7.935452	18.07	<.0001
subarea	2	4596.527340	2298.263670	5234.86	<.0001
codebet	3	283.938646	94.646215	215.58	<.0001
codeyft	3	390.748055	130.249352	296.68	<.0001
codeswo	3	172.807475	57.602492	131.20	<.0001

Table 3. Yearly nominal and standardized CPUE trends of Indian albacore based on Taiwanese longline fishery data set from 1980-2006 using GLM procedure.

Year	Nominal CPUE	Standardized CPUE
1980	11.4441	2.4418
1981	13.7713	3.0190
1982	16.5854	3.3485
1983	11.8313	2.4213
1984	10.6929	1.9607
1985	5.5061	1.7275
1986	7.4106	2.2184
1987	8.1611	2.0689
1988	5.7577	1.9308
1989	2.4169	1.0307
1990	2.3726	0.9083
1991	2.8484	0.9305
1992	6.4693	1.6458
1993	4.7250	1.6993
1994	5.2421	1.5850
1995	3.4220	1.0508
1996	5.2451	1.2089
1997	4.6364	1.5279
1998	6.2231	1.7183
1999	2.9126	0.9712
2000	4.2990	0.9828
2001	5.0349	1.3691
2002	3.0916	1.3640
2003	2.9128	1.4623
2004	2.1185	1.3968
2005	1.5153	1.1226
2006	1.1570	0.8407

Table 4. Quarterly nominal and standardized CPUE trends of Indian albacore based on Taiwanese longline fishery data set from 1980-2006 by GLM procedure.

Year*Quarter	Nominal CPUE	Standardized CPUE
19801	9.558	1.87505
19802	15.750	2.96305
19803	12.020	2.49486
19804	8.628	2.55833
19811	9.294	2.90053
19812	17.878	3.45323
19813	18.553	3.13894
19814	10.038	2.64389
19821	15.653	2.80749
19822	21.936	3.79299
19823	18.903	3.49421
19824	9.894	3.40257
19831	8.982	2.33599
19832	16.644	2.27107
19833	12.915	2.50390
19834	7.815	2.65092
19841	10.308	1.66595
19842	16.307	2.26301
19843	11.844	2.47931
19844	5.039	1.55488
19851	4.459	1.19880
19852	6.936	2.12066
19853	6.278	2.14991
19854	4.169	1.71464
19861	5.017	1.71055
19862	9.947	2.42268
19863	7.548	2.45287
19864	7.292	2.28782
19871	5.726	1.92536
19872	9.704	2.32133
19873	10.272	1.93775
19874	6.557	2.12194
19881	5.290	2.18983
19882	8.115	2.20941
19883	7.454	2.01740
19884	1.882	1.35235
19891	0.821	0.99522
19892	2.411	1.10796
19893	5.534	1.09430
19894	0.816	0.93827
19901	0.408	0.93063
19902	2.641	1.22167
19903	4.282	0.81975
19904	1.530	0.72961
19911	1.099	0.55983
19912	4.504	1.39873
19913	4.848	0.79706
19914	1.488	1.17964
19921	1.120	0.68563
19922	7.038	1.65494
19923	8.558	1.44180
19924	7.055	2.67852
19931	3.535	2.34957
19932	5.479	1.99559
19933	5.859	1.34344
19934	3.562	1.41755
19941	3.333	1.71154
19942	6.790	1.96371
19943	6.240	0.88903
19944	4.386	1.92166
19951	3.394	1.67359
19952	4.470	0.89562
19953	3.622	0.44291
19954	2.310	1.44868
19961	4.219	1.72184
19962	6.840	1.28553
19963	6.633	0.60972
19964	2.954	1.33953
19971	2.925	1.68068
19972	6.956	1.79172
19973	7.268	1.08661
19974	1.821	1.67667
19981	1.943	1.67192
19982	9.986	2.06476
19983	13.832	1.51374
19984	0.756	1.61978
19991	0.886	0.88248
19992	4.159	1.11220
19993	4.711	1.09726
19994	1.717	0.80209
20001	0.970	0.95006
20002	5.691	1.15049
20003	6.372	0.89721
20004	3.665	0.91919
20011	1.616	1.06374
20012	6.084	1.22310
20013	7.019	1.39379
20014	5.382	1.96160
20021	1.033	1.39427
20022	4.307	1.55283
20023	5.216	1.27711
20024	1.469	1.23906
20031	1.321	1.42993
20032	2.969	1.59240
20033	5.033	1.31641
20034	2.967	1.55762
20041	1.707	1.45671
20042	3.557	1.94358
20043	2.456	1.20472
20044	1.100	1.12830
20051	0.961	1.33829
20052	1.652	1.21158
20053	2.400	1.03575
20054	1.146	0.91695
20061	0.631	1.06261
20062	1.238	1.14339
20063	2.842	0.51042
20064	0.870	0.65856

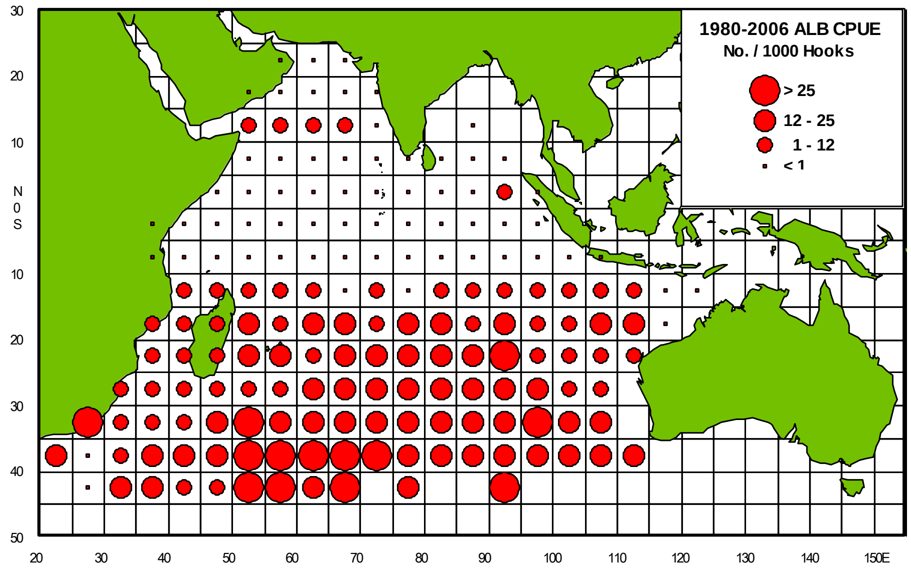

Figure 1. Geographic distribution of Indian albacore nominal CPUE (No./1000 Hooks) based on Taiwanese longline fishery data set from 1980 to 2006.

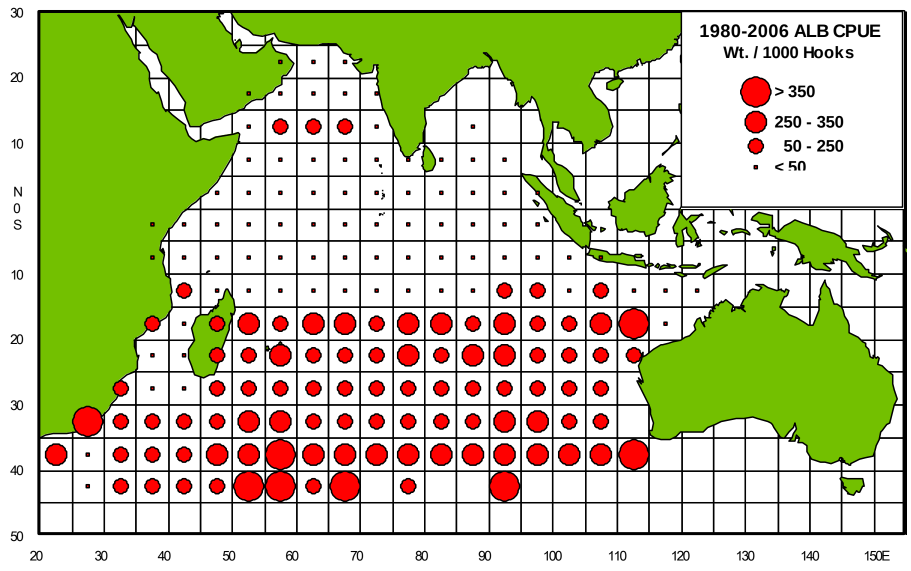

Figure 2. Geographic distribution of Indian albacore nominal CPUE (Wt./1000 Hooks) based on Taiwanese longline fishery data set from 1980 to 2006.

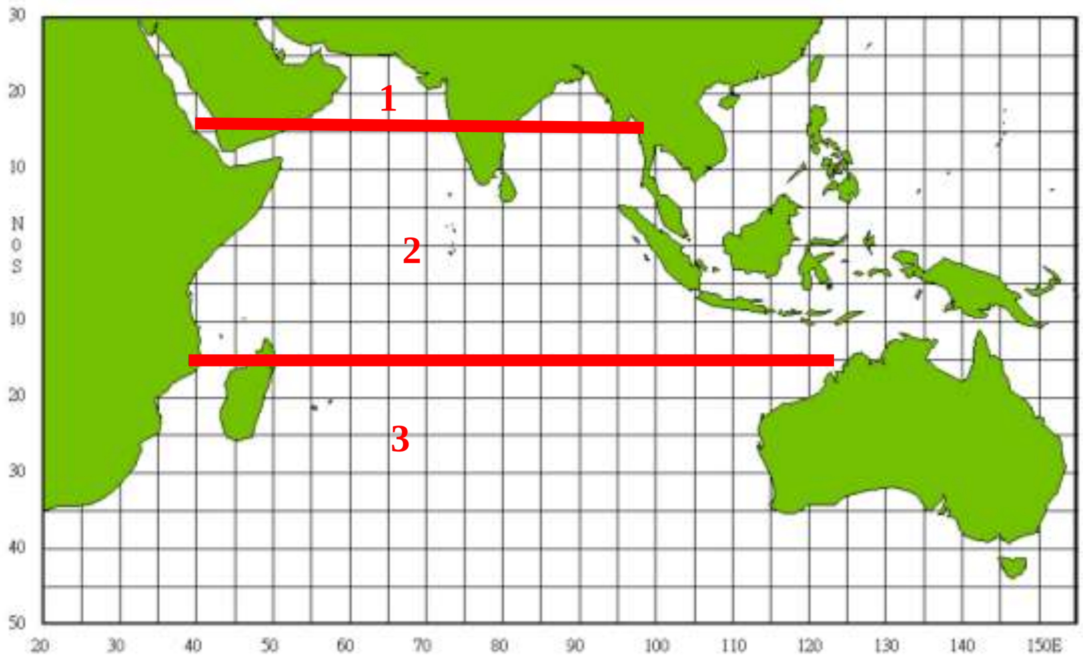

Figure 3. Subarea delineation for Indian albacore habitat.

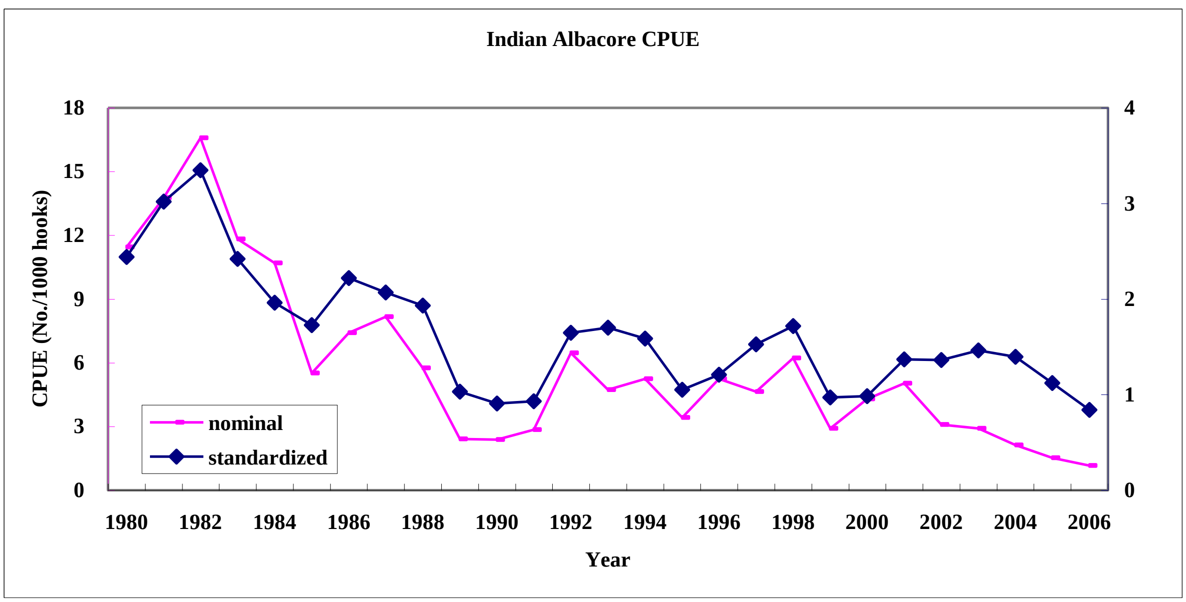

Figure 4. Yearly nominal and standardized CPUE (No/1000 Hooks) trends of Indian albacore based on Taiwanese longline fishery data set from 1980 to 2006.

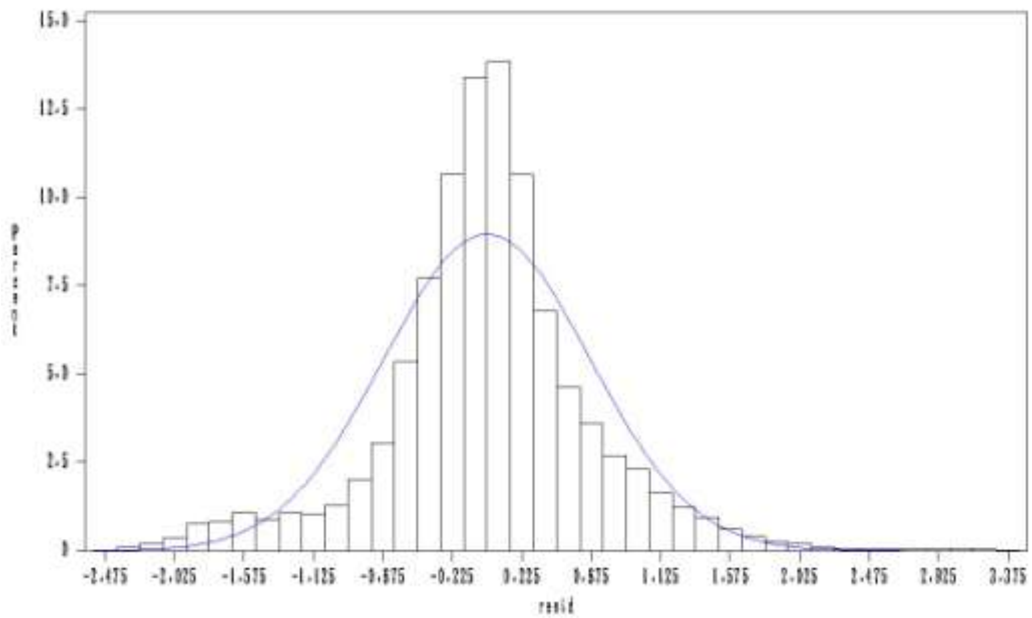

Figure 5. Distribution of normalized residual obtained from yearly GLM model.

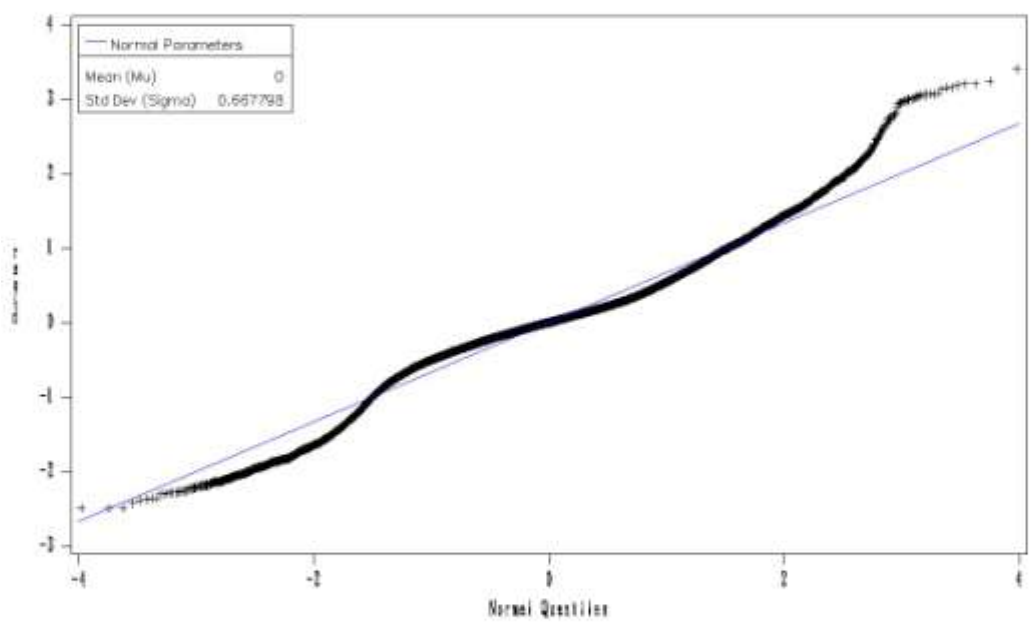

Figure 6. The Q-Q plot for residuals obtained from yearly GLM model.

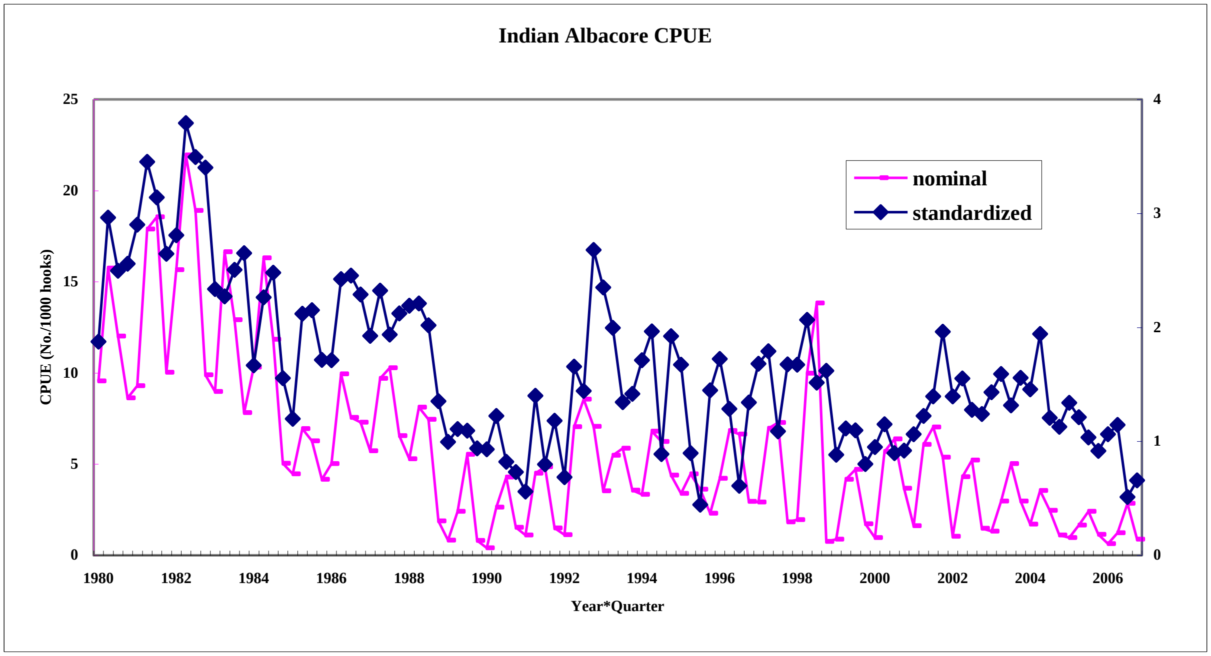

Figure 7. Quarterly nominal and standardized CPUE (No./1000 Hooks) trends of Indian albacore based on Taiwanese longline fishery data set from 1980 to 2006.

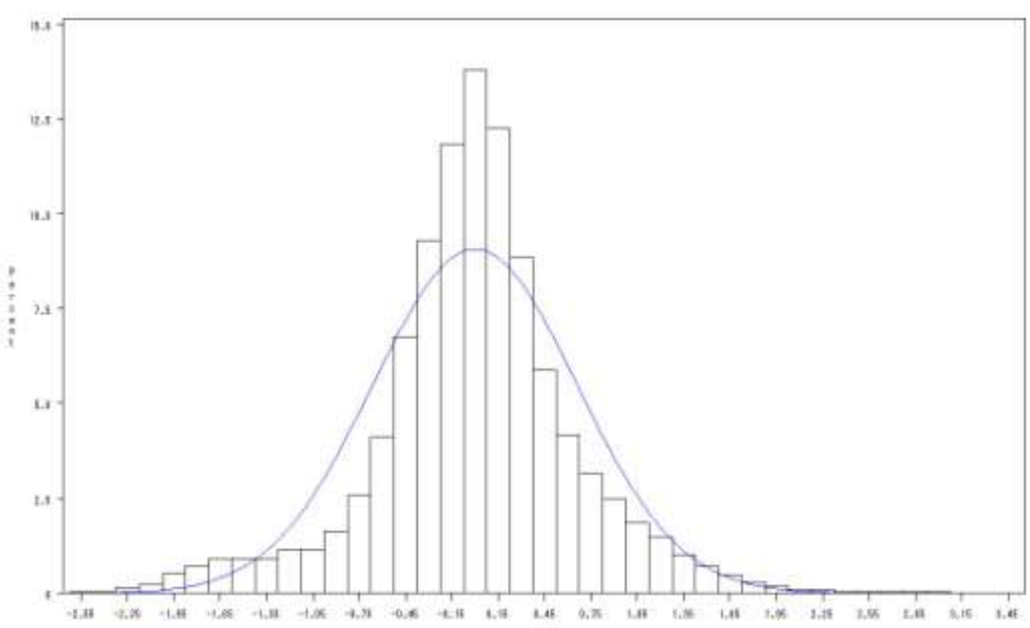

Figure 8. Distribution of normalized residual obtained from quarterly GLM model.

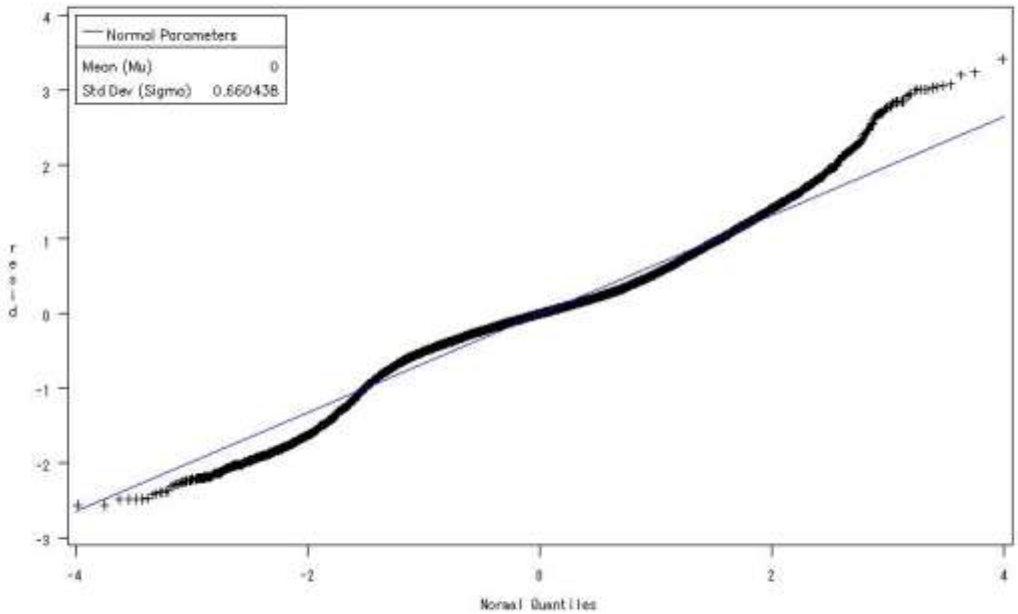

Figure 9. The Q-Q plot for residuals obtained from quarterly GLM model.