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Standardized CPUE of Indian albacore *(Thunnus alalunga)* based on Taiwanese longline catch and effort statistics dating from 1980 to 2010 (Draft: September 05, 2011)

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SUMMARY

Standardized abundance indices of Indian albacore, dating from 1980 to 2010, based on Taiwanese longline catch and effort statistics by using Generalized Liner Model (GLM) procedure were carried out in present study. Four subareas, subdivided by nominal CPUE composition stemmed from area-time catch specifications, as well as factors of year, quarter, bycatch effects of bigeye tuna, yellowfin tuna, and swordfish were used to construct the GLM for obtaining the standardized yearly CPUE trend from 1980 to 2010. Standardized quarterly CPUE series from the 1st quarter of 1980 to the 3rd quarter of 2010 were also performed by using quarter-series, subareas, bycatch effects of bigeye tuna, yellowfin tuna, and swordfish as factors of concern.

The factor of subareas, which may have an indication of habitat specification, always showed the major explanatory factor to the total variance. Thus a better aggregation on those unit statistical blocks, which may have similar habitat specification, is essential for obtaining a better abundance index. Efforts have been made in this paper to improve the delineation of subdivision in the Indian longline fishing areas, based on Taiwanese longline reported area-time catch and effort of tunas.

Yearly CPUE trend of Indian albacore thus obtained indicated that it appeared a decline trend from early 1980s to early 1990s, and leveled off since early 1990s up to early 2000s, then decreased till mid 2000s, and leveled off since mid 2000s up to 2010. Quarterly CPUE trend showed a similar trend as those of yearly fluctuations. Incidentally, a periodic up and down in CPUE series was also notified as a cycle of about ten years. The CPUEs obtained in the late 2000s appeared to be along with the downward trend of such a cycle.

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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 1980-2010 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 2010, 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:

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

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);
ξ_{iklmn} : 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 1.257283, which was obtained by averaging all Taiwanese longliners' nominal albacore CPUE reported from 1980 to 2010 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) 0~0.547945, 0.547945~2.41046, 2.41046~5.2182, and greater than 5.2182 for bigeye tuna; (2) 0~0.336078, 0.336078~1.15213, 1.15213~2.76861, and greater than 2.76861 for yellowfin tuna; and (3) 0~0.0670603, 0.0670603~0.27402, 0.27402~ 0.623344, and greater than 0.623344 for swordfish, accordingly.

For elucidating geographical distribution characters of Indian albacore resource, an aggregated (from 1980 to 2010) 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 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 1980s to early 1990s, leveled off since early 1990s up to early 2000s, then decreased till mid 2000s, and leveled off since mid 2000s up to 2010. 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. Logbooks 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 manipulations, will give a more persuasive resultant CPUE trend than current endeavours.

ACKNOWLEDGMENTS

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Table 1. Analysis of variance on standardizing Indian albacore yearly CPUE using Taiwanese longline fishery data set from 1980 to 2010 by GLM procedure.

Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	45	21219.19421	471.53765	1021.94	<.0001
Error	21111	9740.92741	0.46141		
Corrected Total	21156	30960.12161			
R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean		
0.685372	56.81843	0.679275	1.195519		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	30	816.52482	27.217494	58.99	<.0001
quarter	3	48.893871	16.297957	35.32	<.0001
subarea	3	5593.087095	1864.362365	4040.53	<.0001
codebet	3	289.782795	96.594265	209.34	<.0001
codeyft	3	397.126831	132.375610	286.89	<.0001
codeswo	3	161.990673	53.996891	117.02	<.0001

Table 2. Analysis of variance of standardized Indian albacore quarterly CPUE using Taiwanese longline fishery data set from 1980 to 2010 by GLM procedure.

Dependent Variable: Logcpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	134	21406.8182	159.75237	351.53	<.0001
Error	21022	9553.30341	0.45444		
Corrected Total	21156	30960.12161			
R-Square	Coeff Var	Root MSE	Logcpuen_alb Mean		
0.691432	56.38755	0.674124	1.195519		

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yq	122	1052.172054	8.624361	18.98	<.0001
subarea	3	5509.571207	1836.523736	4041.26	<.0001
codebet	3	289.669893	96.556631	212.47	<.0001
codeyft	3	394.131741	131.377247	289.10	<.0001
codeswo	3	154.013784	51.337928	112.97	<.0001

Table 3. Yearly nominal and standardized CPUE trends of Indian albacore based on Taiwanese longline fishery data set from 1980-2010 using GLM procedure.

Year	Nominal CPUE	Standardized CPUE
1980	11.7119	2.8542
1981	13.9545	3.5064
1982	16.6488	3.8220
1983	11.9178	2.7878
1984	10.7533	2.3658
1985	5.6244	2.1189
1986	7.4130	2.5203
1987	8.1611	2.3104
1988	5.8797	2.2875
1989	2.4426	1.2759
1990	2.4060	1.1088
1991	2.8944	1.1952
1992	6.4890	1.9089
1993	4.9322	1.9608
1994	5.2778	1.8482
1995	3.6675	1.3704
1996	5.3432	1.5178
1997	4.6424	1.8140
1998	5.3889	2.0027
1999	3.0039	1.2882
2000	4.3604	1.2496
2001	5.1407	1.6999
2002	3.0916	1.6327
2003	2.8430	1.6141
2004	2.1423	1.6374
2005	1.5153	1.3759
2006	1.0290	1.0679
2007	0.8984	1.0347
2008	1.7655	1.0733
2009	1.8006	1.0851
2010	3.0411	1.0645

Table 4. Quarterly nominal and standardized CPUE trends of Indian albacore based on Taiwanese longline fishery data set from 1980-2010 by GLM procedure.

Year*Quarter	Nominal CPUE	Standardized CPUE
19801	10.419	2.3965
19802	15.891	3.4928
19803	12.020	2.7312
19804	8.742	2.9465
19811	10.140	3.6992
19812	17.878	4.0001
19813	18.553	3.4496
19814	10.038	2.9951
19821	15.675	3.2839
19822	22.099	4.5814
19823	18.903	3.8934
19824	9.912	3.7268
19831	9.447	2.9589
19832	16.644	2.5940
19833	12.915	2.7378
19834	7.822	2.9501
19841	10.477	2.1299
19842	16.363	2.7904
19843	11.844	2.8191
19844	5.039	1.8687
19851	4.981	1.8076
19852	6.963	2.4690
19853	6.278	2.4437
19854	4.169	1.9812
19861	5.028	2.0718
19862	9.947	2.7462
19863	7.548	2.7705
19864	7.292	2.4987
19871	5.726	2.1853
19872	9.704	2.4541
19873	10.272	2.1910
19874	6.557	2.4428
19881	5.691	2.7698
19882	8.115	2.5396
19883	7.454	2.2881
19884	1.882	1.6106
19891	0.910	1.2869
19892	2.416	1.3502
19893	5.534	1.3001
19894	0.816	1.1887
19901	0.453	1.0635
19902	2.667	1.5191
19903	4.344	1.0397
19904	1.530	0.8887
19911	1.227	0.9093
19912	4.497	1.5912
19913	4.848	1.0217
19914	1.488	1.4460
19921	1.329	1.0092
19922	7.038	1.8911
19923	8.558	1.6737
19924	7.055	2.9455
19931	3.610	2.6592
19932	6.233	2.4048
19933	5.859	1.5405
19934	3.562	1.6012
19941	3.323	1.8508
19942	6.859	2.3233
19943	6.240	1.1165
19944	4.480	2.2667
19951	4.307	2.2882
19952	4.728	1.2854
19953	3.622	0.6134
19954	2.310	1.6468
19961	4.510	2.1816
19962	6.923	1.6258
19963	6.667	0.8429
19964	2.964	1.5675
19971	2.928	2.0058
19972	6.969	2.0966
19973	7.271	1.3925
19974	1.821	1.8804
19981	1.815	1.7990
19982	8.287	2.3879
19983	9.571	1.8594
19984	2.026	1.9605
19991	1.061	1.2001
19992	4.357	1.5025
19993	4.711	1.3821
19994	1.745	1.0888
20001	1.052	1.3351
20002	5.688	1.3768
20003	6.371	1.0831
20004	3.895	1.2217
20011	1.900	1.4107
20012	6.122	1.5018
20013	7.055	1.7060
20014	5.499	2.3932
20021	1.033	1.6842
20022	4.307	1.8804
20023	5.216	1.5433
20024	1.469	1.4292
20031	1.156	1.5640
20032	3.001	1.8516
20033	4.899	1.4835
20034	2.563	1.6054
20041	1.728	1.7006
20042	3.587	2.3310
20043	2.479	1.3666
20044	1.114	1.3486
20051	0.961	1.6113
20052	1.652	1.4846
20053	2.400	1.2888
20054	1.146	1.1379
20061	0.726	1.2641
20062	1.223	1.3099
20063	2.216	0.7196
20064	0.338	1.0505
20071	0.179	1.0309
20072	0.513	1.0436
20073	3.116	0.9543
20074	0.832	1.0872
20081	0.559	0.8784
20082	2.497	1.4448
20083	4.554	0.9061
20084	0.841	1.1165
20091	0.683	0.9583
20092	1.404	1.0370
20093	4.153	1.1129
20094	1.379	1.3002
20101	1.062	1.0183
20102	4.829	1.4109
20103	6.033	0.8133

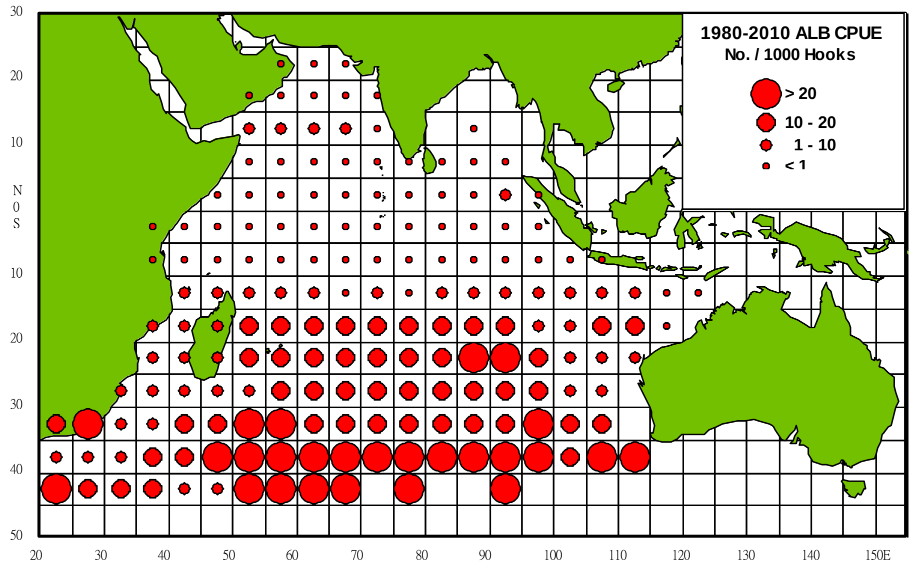

Figure 1. Geographic distribution of Indian albacore nominal CPUE (No./1000 Hooks) based on Taiwanese longline fishery data set from 1980 to 2010.

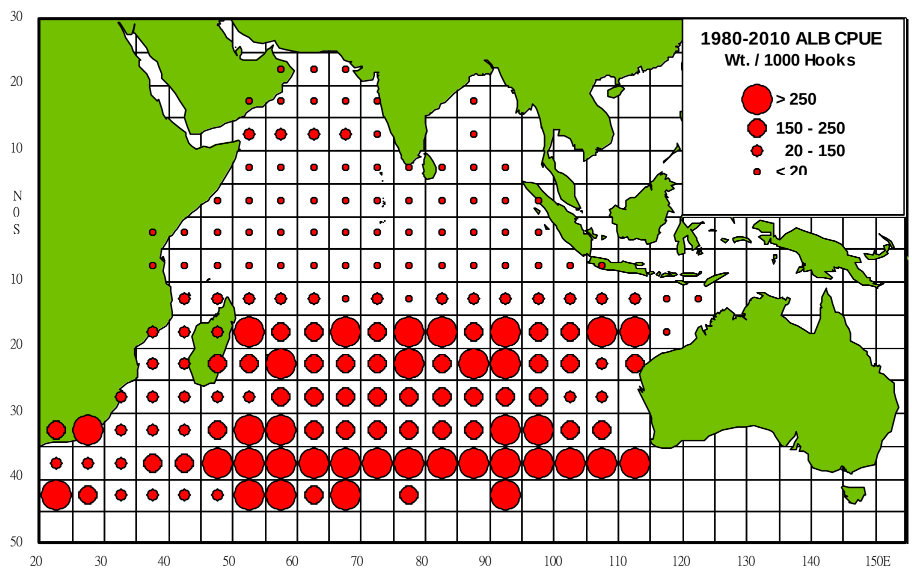

Figure 2. Geographic distribution of Indian albacore nominal CPUE (Wt./1000 Hooks) based on Taiwanese longline fishery data set from 1980 to 2010.

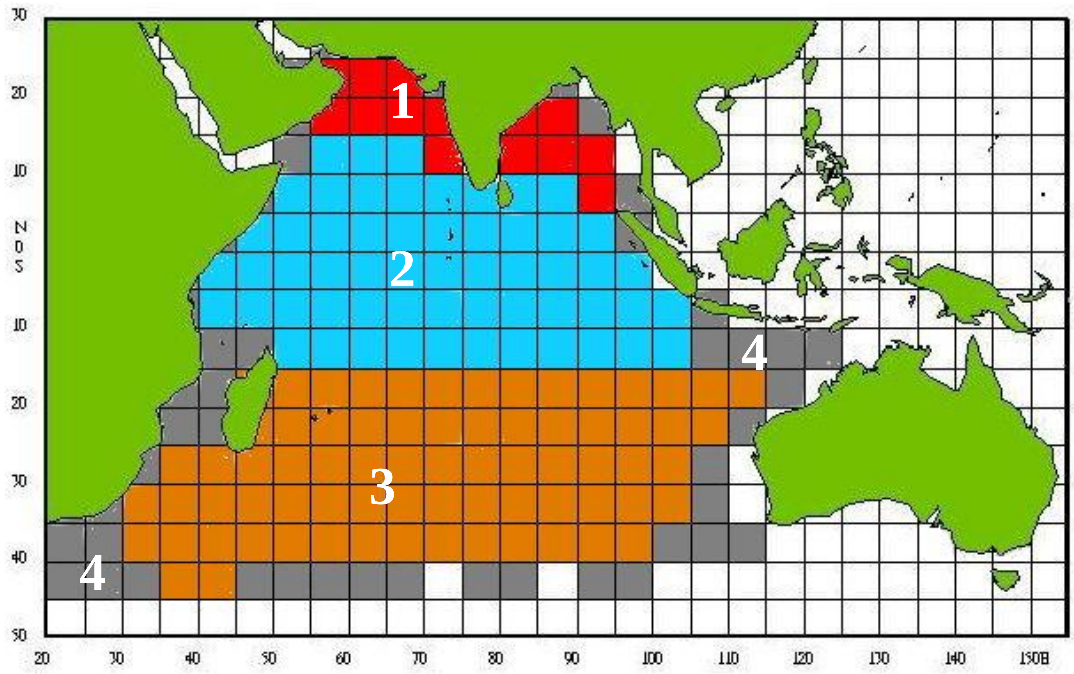

Figure 3. **S**ubarea delineation for Indian albacore habitat.

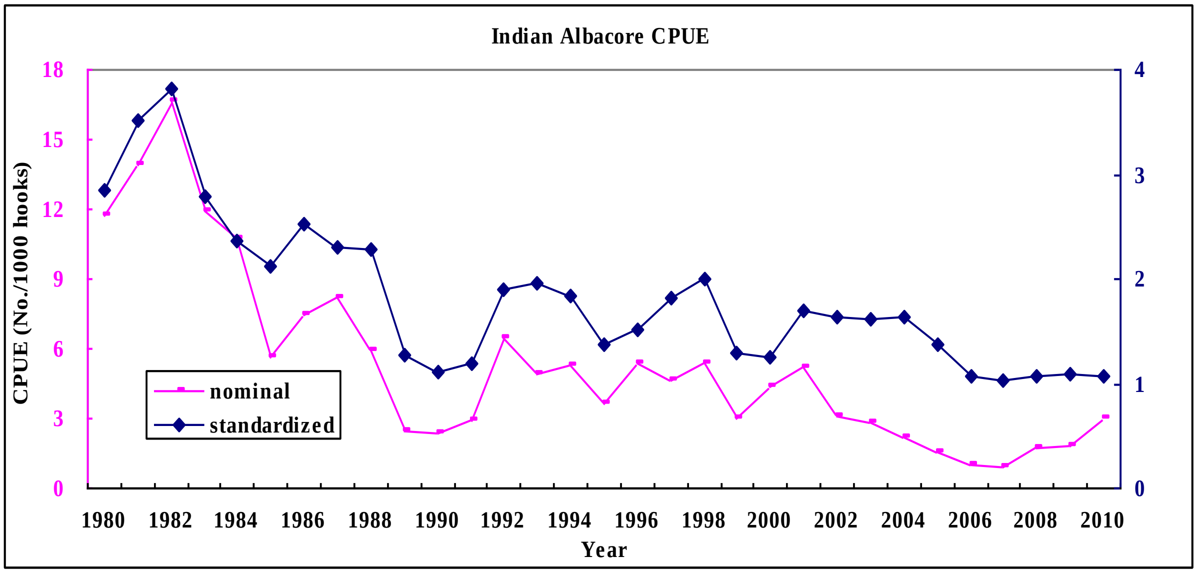

Figure 4. Yearly nominal and standardized CPUE (No/1000 Hooks) trends of Indian albacore based on Taiwanese longline fishery data set from 1980 to 2010.

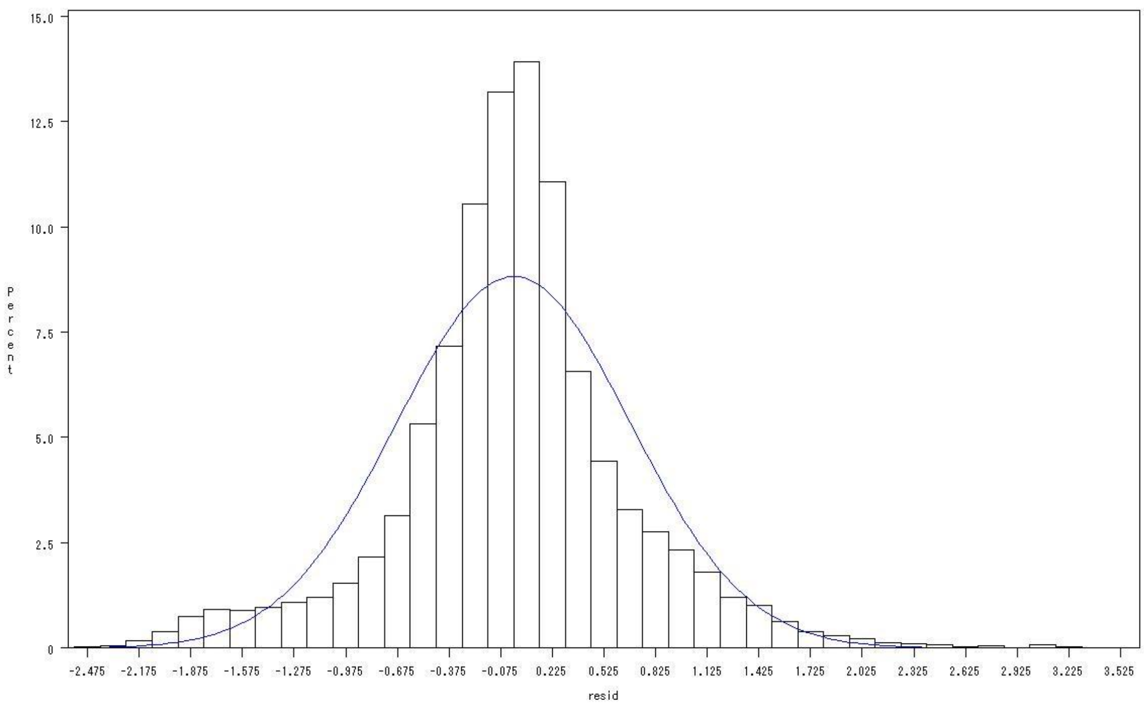

Figure 5. Distribution of normalized residual obtained from yearly GLM model.

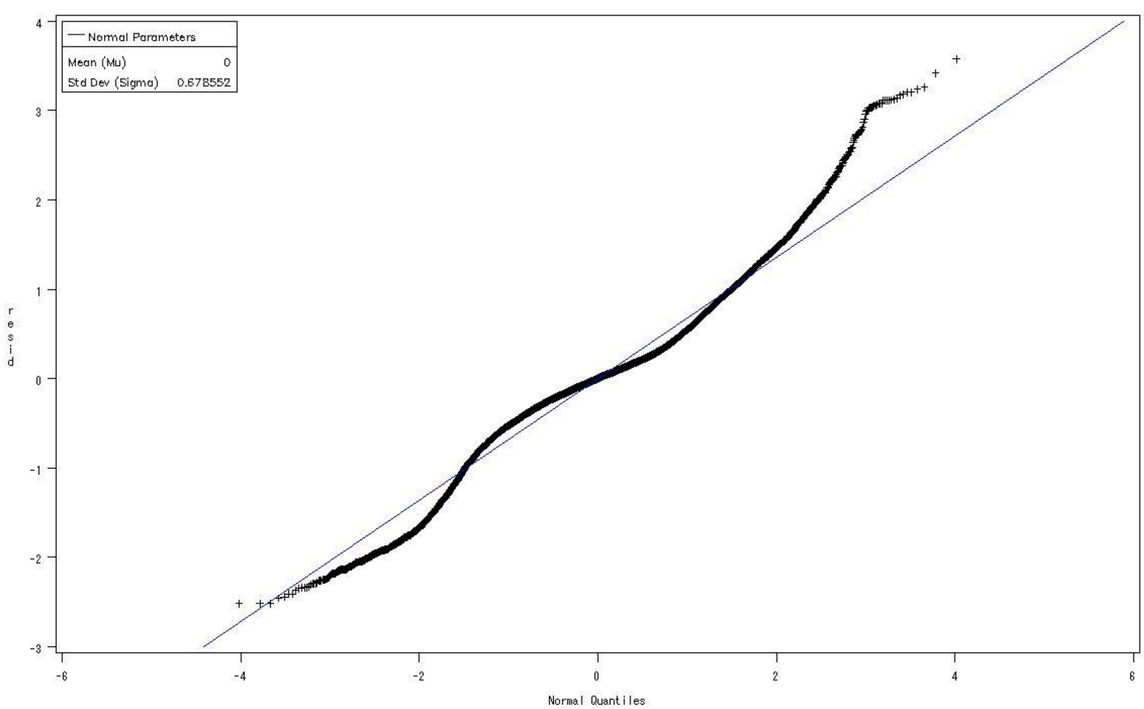

Figure 6. The Q-Q plot for residuals obtained from yearly GLM model.

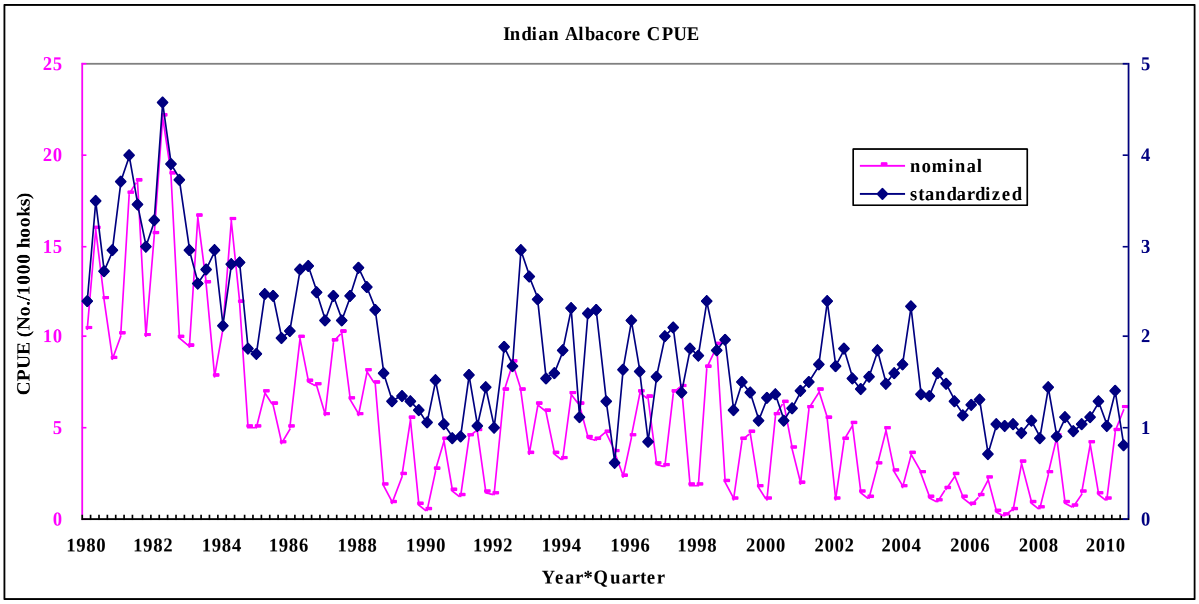

Figure 7. Quarterly nominal and standardized CPUE (No./1000 Hooks) trends of Indian albacore based on Taiwanese longline fishery data set from 1980 to 2010.

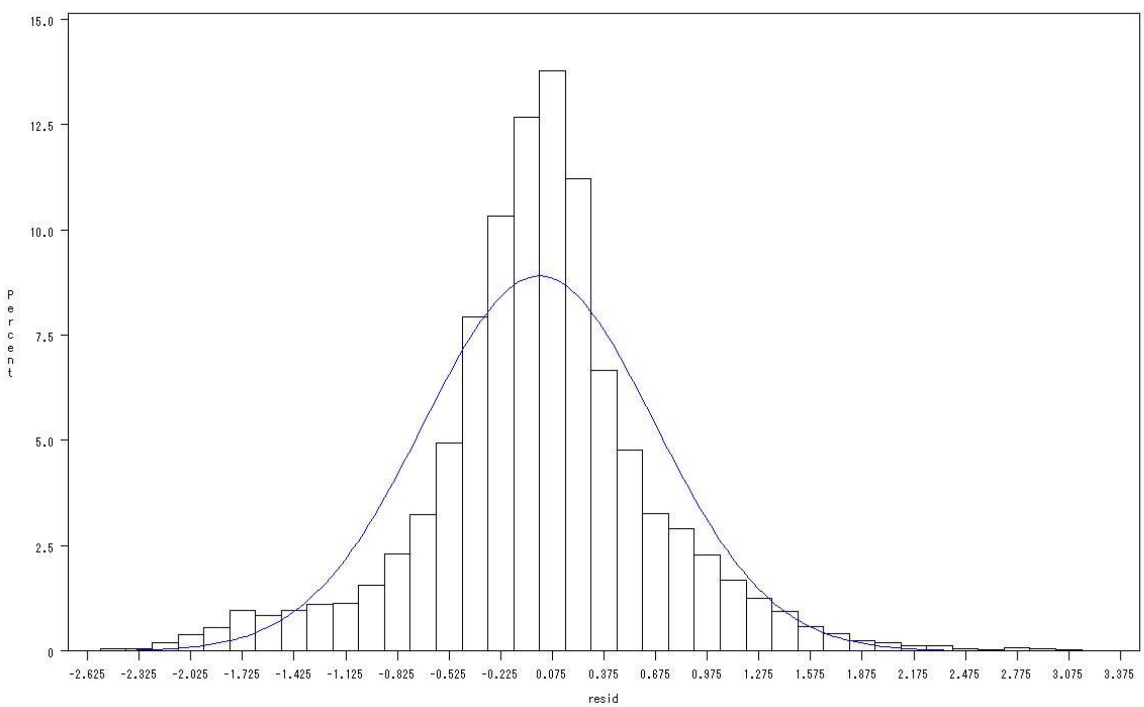

Figure 8. Distribution of normalized residual obtained from quarterly GLM model.

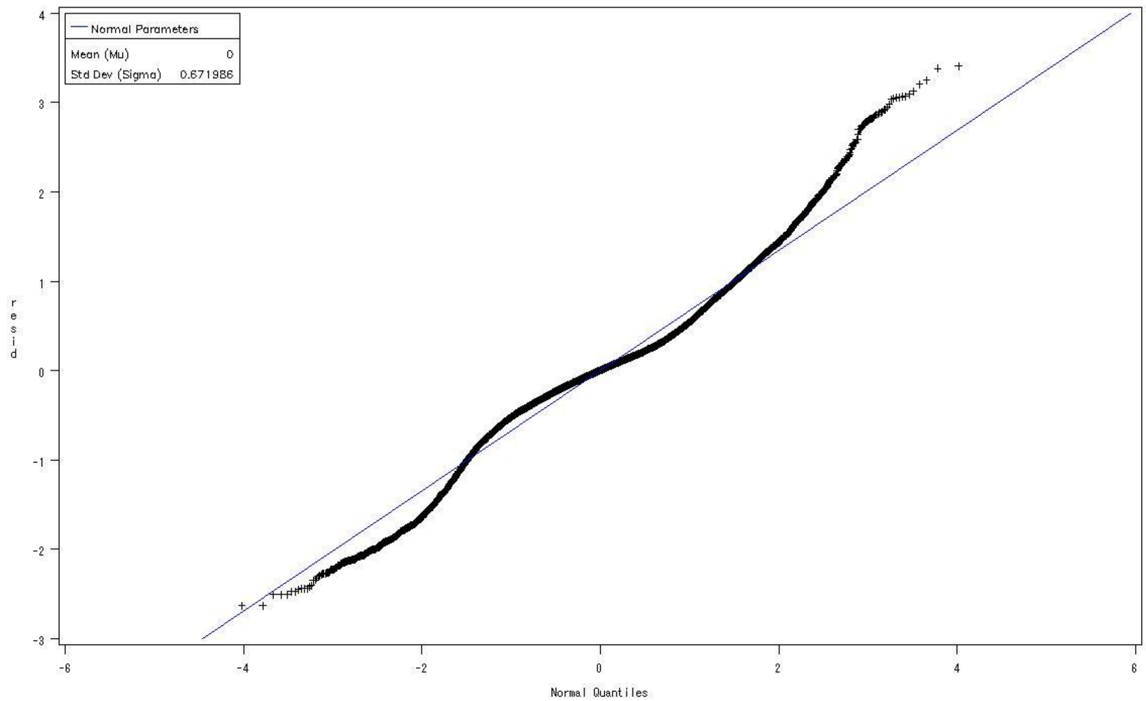

Figure 9. The Q-Q plot for residuals obtained from quarterly GLM model.