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Standardized CPUE of Indian albacore *(Thunnus alalunga)* based on Taiwanese longline catch and effort statistics dating from 1980 to 2011

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SUMMARY

Standardized abundance indices of Indian albacore, dating from 1980 to 2011, based on Taiwanese longline catch and effort statistics by using Generalized Liner Model (GLM) procedure were carried out in present study. 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 2011. Standardized quarterly CPUE series from the 1st quarter of 1980 to the 4th quarter of 2011 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. In present study, the nominal CPUE of three main species and "other fishes" in 5 degree statistical blocks were used to process the hierarchical cluster analysis and resulted in a dendrogram of 4 clusters of fishing block.

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 2011. 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.

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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. Fig. 1 showed the yearly fluctuations of albacore catch and catch composition of main species made by Taiwanese longline fisheries, 1980-2011. It is clear that catch rate of albacore was decreased, yet bigeye and yellowfin tunas were increased greatly after 1985. However, the total catch rate of these three main species was less than 50% after 2006.

The main purposes of this study were thus to standardize the Indian albacore abundance indices, based on Taiwanese 1980-2011 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 logbooks data of Taiwanese longline vessels and task2 data which was compiled from logbooks and aggregated by month and by 5 degree statistical block, from 1980 to 2011, provided by Overseas Fisheries Development Council of Taiwan were used for the cluster analysis to define the subareas and for the GLM analysis to standardize abundance indices of Indian albacore, respectively. The data in 2011 is preliminary. Nominal CPUE was defined as catch in number per 1,000 hooks.

The nominal CPUE by 5 degree statistical block of albacore, bigeye tuna, yellowfin tuna and “other fishes” were used to conduct the hierarchical cluster analysis. Cluster analysis was performed by using SAS statistical package (version 9.3).

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:

$$Ln(CPUE_{ijklmn}+const)=\mu+YEAR_i+QUARTER_j+SUBAREA_k+BET_l+YFT_m+SWO_n+\xi_{ijklmn}$$

where

Ln: natural logarithm;

$CPUE_{ijklmn}$: nominal albacore CPUE (catch in number per 1,000 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;

BET_l: effect of bycatch (bigeye tuna);

YFT_m: effect of bycatch (yellowfin tuna);

SWO_n: effect of bycatch (swordfish);

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

Quarterly generalized linear model with normal error structure:

$$Ln(CPUE_{iklmn}+const)=\mu+QUARTER\text{-}SERIES_i+SUBAREA_k+BET_l+YFT_m+SWO_n+\xi_{iklmn}$$

where

Ln: natural logarithm;

$CPUE_{iklmn}$: nominal albacore CPUE (catch in number per 1,000 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;

BET_l: effect of bycatch (bigeye tuna);

YFT_m: effect of bycatch (yellowfin tuna);

SWO_n: effect of bycatch (swordfish);

ξ_{iklmn}: error with distribution character of $N(0,\sigma^2)$.

SAS Ver. 9.3 statistical package was also used in both cases to obtain solutions.

RESULTS AND DISCUSSION

The result of clustering analysis based on the nominal CPUE by 5 degree statistical block of albacore, bigeye tuna, yellowfin tuna and "other fishes", 1980-2011, showed a clear separation of 4 clusters of fishing block (Fig. 2). Although cluster 1 and cluster 4 seemed to be closely nearby, it is determined that cluster 1 corresponding to yellowfin and cluster 4 appeared to be an independent cluster based on its catch composition is different from others. Table 1 showed Taiwanese longline fisheries operated in these 4 subareas have apparently different catch composition of main species, i.e., yellowfin tuna (subarea 1), bigeye and yellowfin tunas (subarea 2), albacore tuna (subarea 3) and "other species" (subarea 4). These 4 clusters are located in totally different area of Indian Ocean, namely subarea 1-4 respectively (Fig. 3) and were used in GLM analysis.

A constant of 0.62107, which was obtained by averaging all Taiwanese longliners' nominal albacore CPUE reported from 1980 to 2011 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 quartile level. The discrete quartile values used for grouping nominal CPUEs were: (1) 0~0.54069, 0.54069~2.41761, 2.41761~5.22255, and greater than 5.22255 for bigeye tuna; (2) 0~0.33032, 0.33032~1.13102, 1.13102~2.73208, and greater than 2.73208 for yellowfin tuna; and (3) 0~0.06845, 0.06845~0.27362, 0.27362~ 0.61848, and greater than 0.61848 for swordfish, accordingly.

The ANOVA tables, as shown in Table 2 and 3, 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 4, 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 2011. 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 was not far from normal distribution.

The nominal quarterly CPUE trend and its respective standardized quarterly CPUE series thus obtained were tabulated in Table 5, 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 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 not far from normal distribution.

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 1980s to mid 1990s, in particular, perhaps 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.

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Table 1 Catch compositions, by subarea, of Taiwanese longline fisheries, 1980-2011.

species	Subarea1		Subarea2		Subarea3		Subarea4	
	CPUE (ind./10^3hooks)	Catch ratio (%)	CPUE (ind./10^3hooks)	Catch ratio (%)	CPUE (ind./10^3hooks)	Catch ratio (%)	CPUE (ind./10^3hooks)	Catch ratio (%)
ALB	0.01	0.06	0.38	3.66	14.46	66.62	3.15	7.24
BET	0.34	2.03	5.44	52.15	1.47	6.77	1.72	3.95
YFT	14.67	86.56	2.87	27.53	0.75	3.48	1.94	4.46
BFT	0.00	0.00	0.00	0.01	0.03	0.13	0.01	0.02
SBT	0.00	0.00	0.00	0.00	0.29	1.35	0.13	0.29
TUN	0.00	0.02	0.00	0.04	0.04	0.17	0.00	0.01
SWO	0.47	2.76	0.62	5.92	0.69	3.16	0.87	2.01
MLS	0.40	2.35	0.17	1.60	0.06	0.29	0.14	0.31
BLZ	0.14	0.82	0.18	1.74	0.04	0.18	0.05	0.12
BLM	0.06	0.37	0.03	0.25	0.01	0.05	0.05	0.11
BIL	0.23	1.35	0.06	0.61	0.04	0.18	0.06	0.14
SKJ	0.02	0.11	0.03	0.29	0.04	0.19	0.03	0.06
SKX	0.30	1.79	0.21	2.06	0.20	0.93	2.53	5.80
OTH	0.30	1.79	0.43	4.14	3.58	16.49	32.85	75.49
Total	16.95	100.00	10.44	100.00	21.70	100.00	43.52	100.00

ALB：Albacore, BET：Bigeye tuna, YFT：Yellowfin tuna, BFT：Bluefin tuna,
SBT：Southern bluefin tuna, TUN：Other tunas, SWO：Broadbill swordfish, MLS：Striped marlin,
BLZ：Indo-Pacific blue marlin, BLM：Black marlin, BIL：Other marlins, SKJ：Skipjack, SKX：Sharks,
OTH：Other fishes.

Table 2. Analysis of variance on standardizing Indian albacore yearly CPUE using Taiwanese longline fishery data set from 1980 to 2011 by GLM procedure.

Dependent Variable: Lncpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	46	33431.31243	726.76766	1077.77	<.0001
Error	21685	14622.71291	0.67432		
Corrected Tota	21731	48054.02535			

R-Square	Coeff Var	Root MSE	Lncpuen_alb Mean
0.695703	106.9963	0.821172	0.767477

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	31	1137.97149	36.70876	54.44	<.0001
quarter	3	44.83146	14.94382	22.16	<.0001
subarea	3	9422.22275	3140.74092	4657.61	<.0001
bet	3	404.35202	134.78401	199.88	<.0001
yft	3	514.23652	171.41217	254.20	<.0001
swo	3	226.17009	75.39003	111.80	<.0001

Table 3. Analysis of variance of standardized Indian albacore quarterly CPUE using Taiwanese longline fishery data set from 1980 to 2011 by GLM procedure.

Dependent Variable: Lncpuen_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	139	33709.37873	242.51352	365.04	<.0001
Error	21592	14344.64662	0.66435		
Corrected Tota	21731	48054.02535			

R-Square	Coeff Var	Root MSE	Lncpuen_alb Mean
0.701489	106.2021	0.815077	0.767477

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yq	127	1460.83936	11.50267	17.31	<.0001
subarea	3	9258.08290	3086.02763	4645.18	<.0001
bet	3	403.82042	134.60681	202.61	<.0001
yft	3	514.93138	171.64379	258.36	<.0001
swo	3	216.03071	72.01024	108.39	<.0001

Table 4. Yearly nominal and standardized CPUE trends, with its associated standard error, of Indian albacore based on Taiwanese longline fishery data set from 1980-2011 using GLM procedure.

Year	Nominal CPUE	Standardized CPUE	Standard Error
1980	11.7119	2.2573	0.03072
1981	13.9545	2.6888	0.03544
1982	16.6488	2.9207	0.03433
1983	11.9178	2.1591	0.03399
1984	10.7533	1.8182	0.03706
1985	5.6244	1.5941	0.04089
1986	7.413	1.8400	0.03778
1987	8.1611	1.7369	0.03430
1988	5.8797	1.7114	0.03540
1989	2.4426	0.9563	0.03857
1990	2.406	0.8406	0.03992
1991	2.8944	0.9253	0.04345
1992	6.489	1.4094	0.04780
1993	4.9322	1.4835	0.03282
1994	5.2778	1.3872	0.03043
1995	3.6675	1.0214	0.03048
1996	5.3432	1.0870	0.03077
1997	4.6424	1.3116	0.03108
1998	5.3889	1.4907	0.03117
1999	3.0039	0.9841	0.02846
2000	4.3604	0.9233	0.02777
2001	5.1407	1.3111	0.02644
2002	3.0916	1.2635	0.02758
2003	2.843	1.2271	0.02792
2004	2.1423	1.2600	0.02929
2005	1.5153	1.0675	0.02783
2006	1.029	0.8163	0.02998
2007	0.8984	0.7833	0.03104
2008	1.7655	0.8051	0.03285
2009	1.7951	0.8568	0.03250
2010	3.6543	0.9121	0.03502
2011	2.3573	0.8933	0.04549

Table 5. Quarterly nominal and standardized CPUE trends, with its associated standard error, of Indian albacore based on Taiwanese longline fishery data set from 1980-2011 by GLM procedure.

Year*Quarter	Nominal CPUE	Standardized CPUE	Standard Error	Year*Quarter	Nominal CPUE	Standardized CPUE	Standard Error
19801	10.4191	1.8912	0.05769	19961	4.5102	1.5786	0.05621
19802	15.8906	2.7620	0.05781	19962	6.9232	1.1273	0.06772
19803	12.0202	2.1733	0.05898	19963	6.6674	0.6363	0.05672
19804	8.7421	2.3391	0.06215	19964	2.9636	1.1226	0.05980
19811	10.1398	2.9072	0.06929	19971	2.9278	1.4817	0.06180
19812	17.8781	3.0049	0.06840	19972	6.9688	1.4769	0.06619
19813	18.5532	2.5760	0.06789	19973	7.2706	1.0215	0.05591
19814	10.0376	2.3711	0.06839	19974	1.8206	1.3619	0.05829
19821	15.6753	2.4540	0.06457	19981	1.8148	1.2991	0.06720
19822	22.0985	3.3481	0.06951	19982	8.2871	1.7460	0.06019
19823	18.9026	3.0050	0.06470	19983	9.5715	1.4349	0.05694
19824	9.9122	3.0338	0.06637	19984	2.0263	1.4756	0.05917
19831	9.4467	2.3183	0.06247	19991	1.0610	0.9134	0.05796
19832	16.6443	1.9158	0.06379	19992	4.3571	1.1384	0.05404
19833	12.9145	2.1329	0.06334	19993	4.7113	1.0948	0.05507
19834	7.8222	2.3862	0.07320	19994	1.7455	0.8164	0.05405
19841	10.4773	1.6543	0.07038	20001	1.0516	1.0122	0.05606
19842	16.3632	2.0712	0.07162	20002	5.6880	0.9883	0.05216
19843	11.8437	2.1337	0.07214	20003	6.3713	0.8246	0.05114
19844	5.0386	1.5204	0.07293	20004	3.8952	0.8859	0.05633
19851	4.9806	1.3945	0.07428	20011	1.9002	1.0861	0.05036
19852	6.9627	1.8248	0.08126	20012	6.1221	1.1120	0.04878
19853	6.2776	1.8154	0.08466	20013	7.0547	1.3637	0.05111
19854	4.1688	1.5040	0.07955	20014	5.4994	1.8816	0.05380
19861	5.0280	1.4895	0.07654	20021	1.0326	1.3073	0.05297
19862	9.9471	1.9184	0.08094	20022	4.3074	1.4363	0.05130
19863	7.5475	2.0541	0.06909	20023	5.2163	1.2540	0.05163
19864	7.2915	1.8994	0.06817	20024	1.4691	1.0623	0.05711
19871	5.7258	1.6040	0.07027	20031	1.1559	1.2006	0.05322
19872	9.7036	1.8092	0.06539	20032	3.0015	1.3884	0.05514
19873	10.2719	1.7010	0.06357	20033	4.8993	1.1660	0.04995
19874	6.5568	1.8610	0.06642	20034	2.5631	1.1894	0.05804
19881	5.6909	2.0932	0.06664	20041	1.7284	1.2826	0.05664
19882	8.1149	1.8571	0.07089	20042	3.5875	1.8022	0.06034
19883	7.4541	1.7384	0.06625	20043	2.4786	1.1010	0.05278
19884	1.8816	1.2153	0.07080	20044	1.1140	1.0238	0.05724
19891	0.9097	0.9449	0.07654	20051	0.9607	1.2684	0.05157
19892	2.4162	1.0376	0.07204	20052	1.6521	1.1161	0.05434
19893	5.5338	0.9892	0.07578	20053	2.4000	1.0154	0.05335
19894	0.8157	0.8682	0.07625	20054	1.1460	0.8908	0.05498
19901	0.4526	0.7809	0.08196	20061	0.7259	0.9839	0.05523
19902	2.6670	1.1139	0.08549	20062	1.2235	1.0084	0.06459
19903	4.3437	0.8292	0.07082	20063	2.2163	0.5595	0.05675
19904	1.5295	0.6899	0.07678	20064	0.3383	0.7860	0.05811
19911	1.2273	0.7200	0.07913	20071	0.1791	0.7718	0.06208
19912	4.4974	1.1769	0.09447	20072	0.5128	0.7582	0.06572
19913	4.8478	0.8117	0.07975	20073	3.1162	0.7432	0.05938
19914	1.4881	1.1343	0.09007	20074	0.8325	0.8421	0.05587
19921	1.3290	0.7635	0.11341	20081	0.5585	0.6646	0.06272
19922	7.0380	1.3492	0.09781	20082	2.4967	1.0642	0.06323
19923	8.5579	1.2542	0.08273	20083	4.5544	0.6882	0.06725
19924	7.0545	2.2374	0.08868	20084	0.8411	0.8437	0.06271
19931	3.6099	2.0071	0.06980	20091	0.6748	0.7428	0.05899
19932	6.2332	1.8635	0.06387	20092	1.3808	0.7777	0.06196
19933	5.8594	1.1496	0.06627	20093	4.1955	0.9185	0.06280
19934	3.5615	1.2160	0.05663	20094	1.3453	1.0736	0.06895
19941	3.3228	1.4355	0.05813	20101	1.3831	0.8450	0.06380
19942	6.8585	1.6916	0.05951	20102	5.9388	1.0420	0.06716
19943	6.2401	0.8538	0.05986	20103	5.9816	0.8288	0.07173
19944	4.4802	1.7074	0.05838	20104	2.0404	0.9628	0.07082
19951	4.3073	1.7310	0.06080	20111	1.0589	0.6878	0.07207
19952	4.7277	0.9501	0.06014	20112	4.1052	1.2188	0.08544
19953	3.6218	0.4865	0.05759	20113	3.2462	1.0535	0.09272
19954	2.3096	1.2233	0.05793	20114	0.1032	0.7291	0.13096

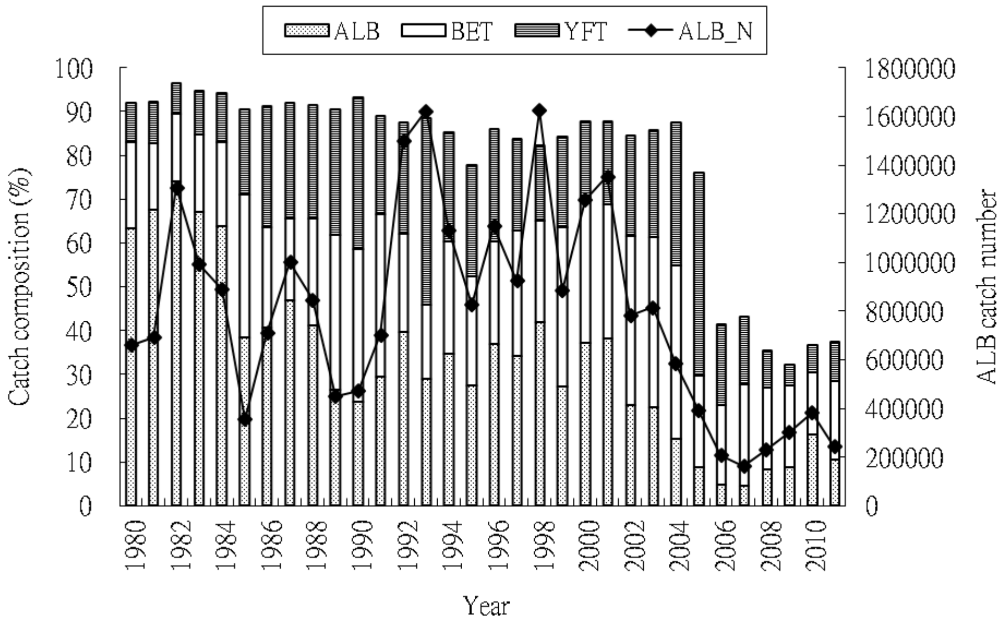

Figure 1. Yearly fluctuations of albacore catch and catch composition of main species made by Taiwanese longline fisheries, 1980-2011.

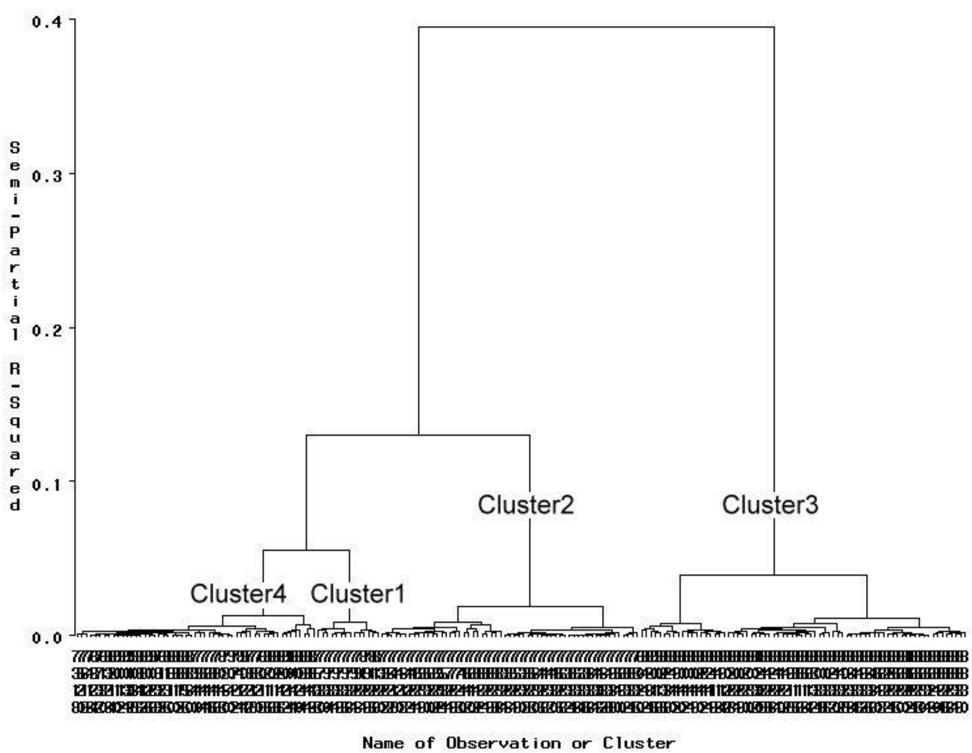

Figure 2. The result of cluster analysis in present study.

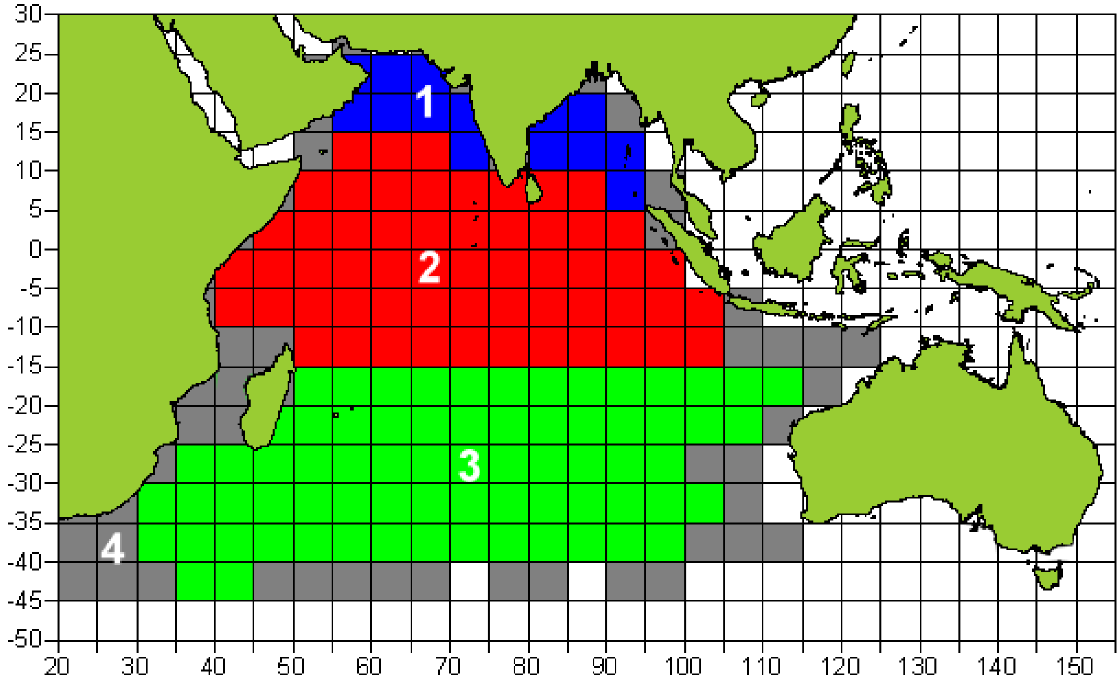

Figure 3. Map showing the 4 subareas of Indian Ocean, based on the result of cluster analysis on Taiwanese longline data, 1980-2011.

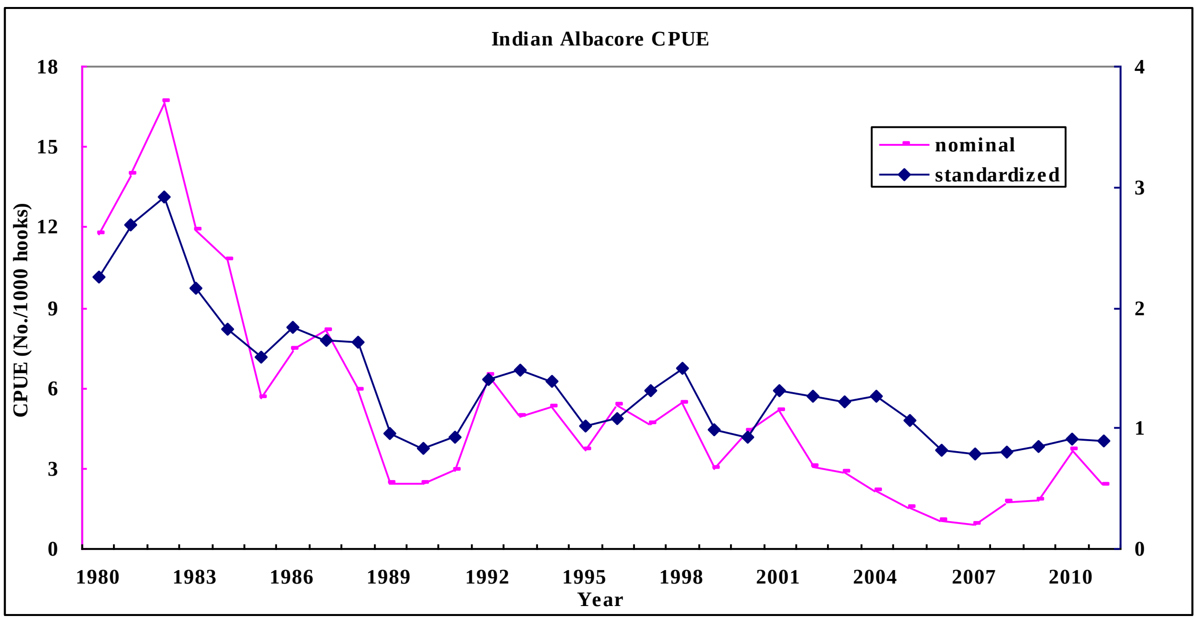

Figure 4. Yearly nominal and standardized CPUE (No/1000 Hooks) trends of Indian albacore based on Taiwanese longline fishery data set from 1980 to 2011.

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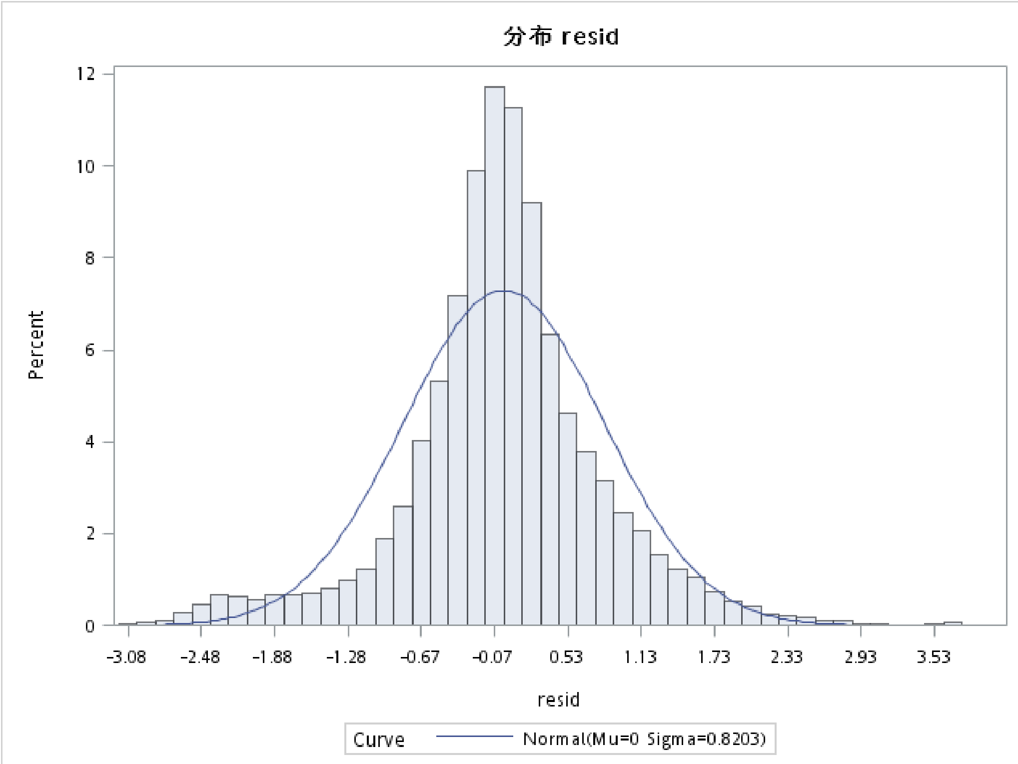

Figure 5. Distribution of normalized residual obtained from yearly GLM model.

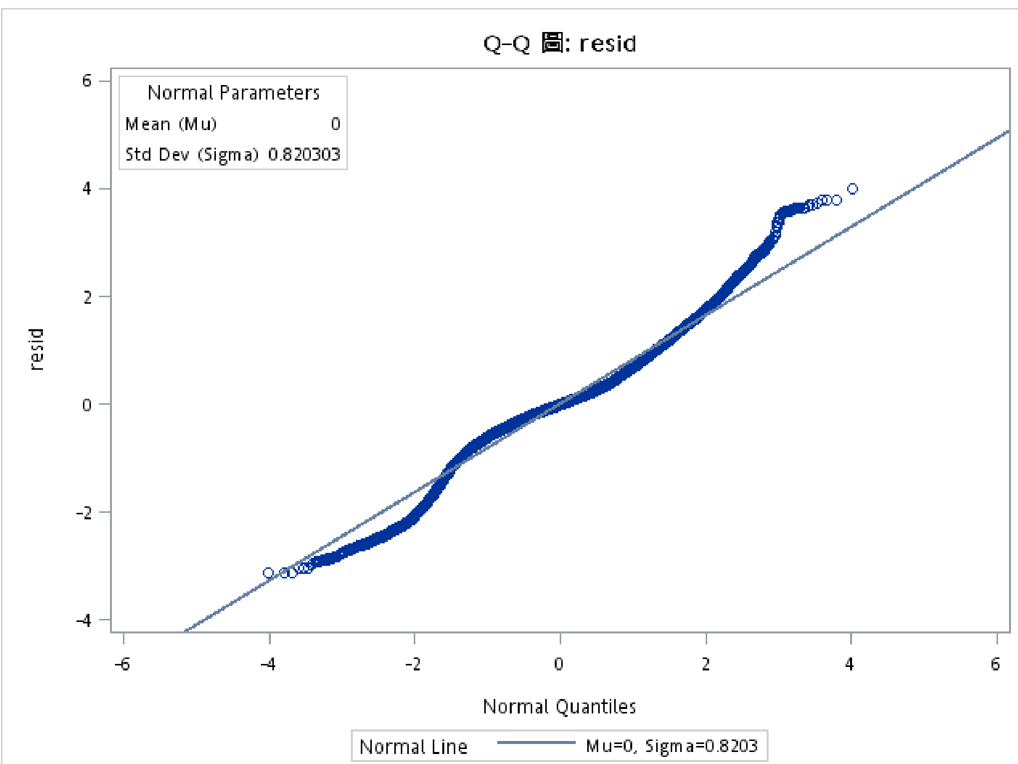

Figure 6. The Q-Q plot for residuals obtained from yearly GLM model.

Received: 20 August, 2012

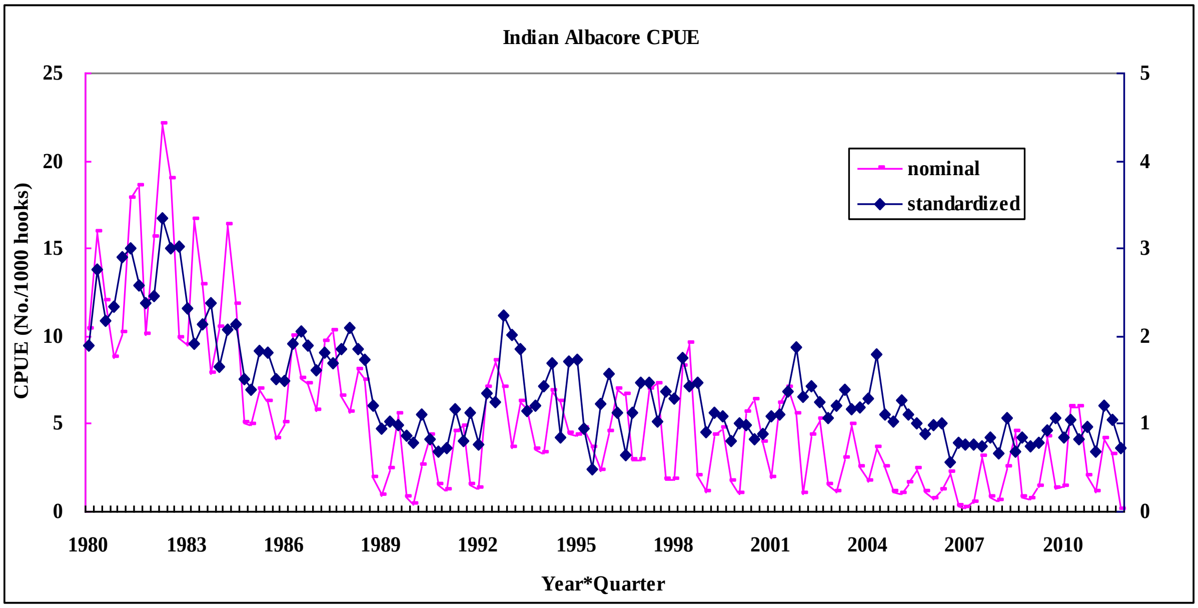

Figure 7. Quarterly nominal and standardized CPUE (No./1000 Hooks) trends of Indian albacore based on Taiwanese longline fishery data set from 1980 to 2011.

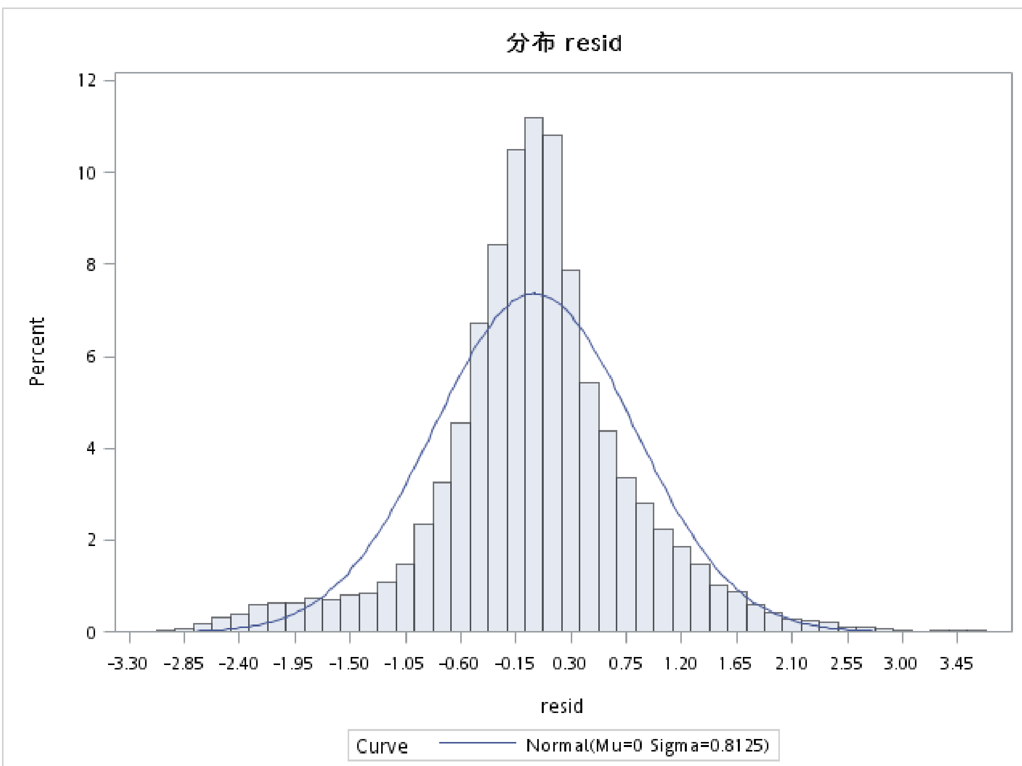

Figure 8. Distribution of normalized residual obtained from quarterly GLM model.

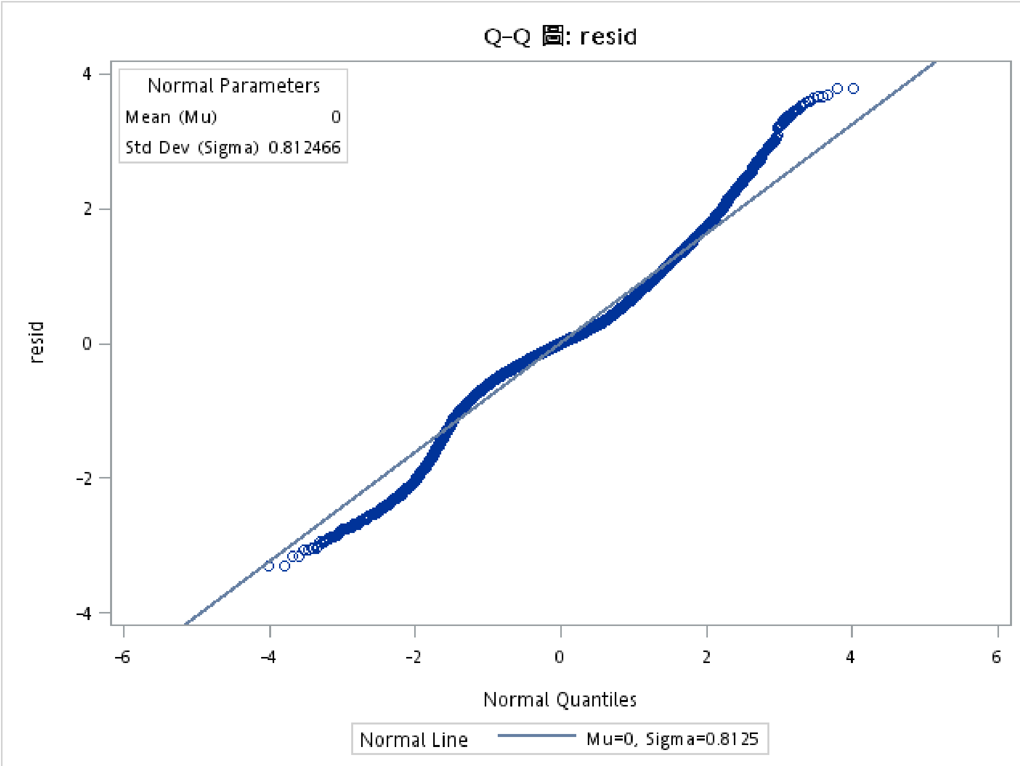

Figure 9. The Q-Q plot for residuals obtained from quarterly GLM model.