OPEN ACCESS

International

Journal

Of Modern Engineering Research (IJMER)

CPUE Standardization on Southern Atlantic Albacore, Dating From 1967 to 2016, Based On Catch Statistics of Taiwanese Longliners

Feng-Chen Chang*

*Research Scientist, Department of Information, Overseas Fisheries Development Council, Taiwan

Corresponding Author: Feng-Chen Chang

ABSTRACT: *Both the logbooks and the task2 data sets of Taiwanese longliners were scrutinized, by decadal period and 5°-square block, for the geographical distribution characters of four major tuna species and determined the core, presumably allowed, sampling area for obtaining an abundance indices of betterment for albacore resources. This paper used only those Taiwanese fisheries data sets within the proposed core sampling area by the generalized linear model (GLM) standardization analysis for minimizing most noises of non-albacore-targeting data. The core sampling area for South Atlantic albacore thus identified was from 10°S to 45°S and from 55°W to 20°E, yet excluding the small block of 10°S-15°S/10°W-15°E. The catch per unit effort (CPUE), both yearly and quarterly, trends obtained indicated that the abundance in weight of the core albacore sampling area declined from late 1960s to 1990, then increased till mid-1990s, and leveled off since early 2000s up to 2016. Quarterly trend, as compared to its respective yearly trend, often appeared a significant peak per year implied a consistent recruitment pattern of this resource. New fishing management strategy, if applied, will inevitably affected the long-standing-understood status of the stock, because no such factor has ever put into the model consideration.*

Keywords: *Albacore, CPUE standardization, GLM, longline, South Atlantic*

I. INTRODUCTION

1.1 Historical fisheries activities

In the Atlantic Ocean, two stocks of albacore *(Thunnus alalunga)*, 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 t to 35,000 t in the last decade. Taiwanese catch of South Atlantic albacore comprised of 70% or more of the total (Figure 1). 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 Ocean were mainly composed of two types of fishing gears, i.e., regular longliner and deep longliner. The regular longliner, which commenced since 1960s and was also called traditional longliner, was mainly targeting albacore. Since mid-1980s, another type of longliner or so called deep longliner, which equipped with -70 degree centigrade or more freezing capability, was mainly targeting bigeye and yellowfin tunas. Unfortunately, it was not possible until mid-1990s when the logbook reporting system was able to distinguish their major identities by the addition of 'the number of hooks per basket used' in new reporting logbooks. Nevertheless, historic task2 data series compiled by Taiwanese fisheries managerial sectors and reported to ICCAT since late 1960s thus became one of the important data sources to investigate the long-term abundance fluctuation of this resource.

1.2 Taiwanese Fisheries management

For compiling with those new regulation requirements set by ICCAT recommendations, Taiwan Fisheries Agency announced:

(1) fishing only allowed as prior authorization by area and group; initial vessel quota are pre-set, yet later modification will be allowed as long as total catch limits as a whole is not exceed;
(2) for best controlling the fishing procedure not to cross the pre-set red-line, several further management tools are also implemented parallel to the progressive fishing activities, such as: VMS-reporting continuously for monitoring its fishing location; daily fill in catch logbook as well as weekly reporting its weekly total; prior permission for at sea transshipment; verification of catch documents versus weekly reporting;
(3) on-board observer; at-sea inspection; and e-logbook system for a better abide by the ICCAT requirements.

These new establishments inevitably will affect an understanding status of the stock, as compared to those collected through traditional setup. As a result, how to standardize historic information is becoming something we have to concern.

1.3 Standardization CPUE of Taiwanese fleets

How to properly sort out the entanglements of albacore information reported from the regular longliner (targeting albacore) and the deep longliner (targeting bigeye tuna) remained the major difficulty in obtaining a better indicator for albacore abundance. Undertaking this problem, as the attempt, an appropriate area or the best sampling area was investigated and proposed in this analysis for obtaining the better albacore abundance indices.

Both the logbooks (since 1981) and the task2 (since 1967) data sets of Taiwanese longliners were scrutinized, by decadal period and 5º-square block, for the geographical distribution characters of four major tuna species (albacore, bigeye tuna, yellowfin tuna, and swordfish) and identified the core sampling area for obtaining the better abundance indices for albacore resource. This paper used only those Taiwanese fisheries data sets within the proposed core sampling area for the GLM standardization analysis and hopefully able to minimize most noises of non-albacore-targeting data.

II. MATERIALS AND METHODS

2.1 Data

(1) Task1 from 1962 to 2016

Task1 is compiled based on the data of weekly catch report; the total catch from the recovered logbooks; statistical documents reported to the Fisheries Agency; monthly traders' sales records; the verification on settlement of fish sales from the Fisheries Agency; and trading data from the Organization for the Promotion of Responsible Tuna Fishery (OPRT). The historical catch of South Atlantic albacore was showed in Figure 1. Taiwanese catch of South Atlantic albacore peaked in 1987 which was 28,790 t, then decreased and fluctuated between 6,700 t to 21,000 t after 1988.

(2) Logbook from 1981 to 2016

By vessel and daily-summed logbooks data, dating from 1981 to 2016, were compiled. Four species (albacore, bigeye tuna, yellowfin tuna and swordfish) of catches in weight (kg) compiled from logbooks were thus used to conduct the k-means model cluster analysis to determine which vessel belongs to the albacore-catching fleet. Euclidean distances thus obtained were used as a criteria and the cluster centers were determined by least squares method. A confirmation on the scope of distribution pattern appeared by operating albacore fleet will then designated as the core albacore sampling area, which will then applied to the compilation on task2 data format in this study.

(3) Task2 from 1967 to 2016

The task2 data, aggregated by month and 5° statistical block from 1967 to 2016, were compiled. The logbook and task2 data, provided by Overseas Fisheries Development Council of Taiwan, were the major sources of data used in this analysis. Nominal CPUEs were defined as catch in weight per 1,000 hooks.

2.2 The core albacore sampling area

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 is 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.

In order to find the core albacore sampling area for Taiwanese longline fishery, distribution maps of albacore CPUE, albacore catch, effort, proportion of catch by species, and amount of catch by species for each decadal period by Taiwanese longline fishery were used to examine. Four species (albacore, bigeye, yellowfin and swordfish) of catches in weight (kg) compiled from logbooks were thus used to conduct the k-means model cluster analysis to determine which vessel belongs to the albacore-catching fleet. Euclidean distances thus obtained were used as a criteria and the cluster centers were determined by least squares method. A confirmation on the scope of distribution pattern appeared by operating albacore fleet will then designated as the core albacore sampling area, which will then applied to the compilation on task2 data format in this study.

2.3 Models of GLM

A constant, which was obtained by averaging all Taiwanese longliners' nominal albacore CPUE in the core albacore sampling area of South Atlantic Ocean 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 [1].

In the core albacore sampling area, the GLM with normal error structure [2][3][4] 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 and subareas by 5° latitude x 5° longitude. Factors used in the quarterly standardization, however, are quarter-series and subareas by 5° latitude x 5° longitude. The subareas by 5° latitude x 5° longitude were adopted in the model to minimize variations caused by fishing location. The GLM models constructed in present study for yearly and quarterly standardizations are as follows:

Yearly generalized linear model with normal error structure:

$$\mathbf{LOG(CPUE_{ijk}+c)=\mu+YEAR_i+QUARTER_j+SUBAREA_k+\xi_{ijk}}$$

where

LOG: natural logarithm;

$CPUE_{ijk}$: nominal albacore CPUE (catch in weight per 1000 hooks) in year *i*, quarter *j* and subarea *k*;

μ: intercept;

c: constant (10% of the overall mean of nominal albacore CPUE);

$YEAR_i$: main effect of year *i*;

$QUARTER_j$: effect of quarter *j*;

$SUBAREA_k$: effect of subarea *k*;

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

Quarterly generalized linear model with normal error structure:

$$\mathbf{LOG(CPUE_{ik}+c)=\mu+QUARTER\text{-}SERIES_i+SUBAREA_k+\xi_{ik}}$$

where

LOG: natural logarithm;

$CPUE_{ik}$: nominal albacore CPUE (catch in weight per 1,000 hooks) in quarter-series *i* and subarea *k*;

μ: intercept;

c: constant (10% of the overall mean of nominal albacore CPUE);

$QUARTER\text{-}SERIES_i$: main effect of quarter-series *i*;

$SUBAREA_k$: effect of subarea *k*;

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

SAS Ver. 9.4 statistical package was used in both cases to obtain solutions.

III. RESULT AND DISCUSSION

3.1 Cluster analysis

The cluster analysis was used to allocate sets to a main target species, with the goal of removing non-albacore-targeting sets and ensure that albacore catchability was the same across sets retained for the analysis. This approach is further justified by examining trends in regional nominal CPUE by cluster, which shows important contrasts between albacore and non-albacore-targeting clusters.

The result of cluster analysis based on the logbook catches in weight of albacore, bigeye tuna, yellowfin tuna and swordfish from 1981 to 2016 showed a clear separation of 4 clusters (Table 1, Figure 2a and Figure 2b). Taiwanese longline fisheries operated in these 4 clusters had apparently different catch composition of main species, i.e., albacore (cluster 1); albacore, bigeye and yellowfin tunas (cluster 2); albacore (cluster 3); and bigeye and yellowfin tunas (cluster 4). The cluster 1 and cluster 3 can be treated as the albacore fleet. Figures 3-7 showed the geographical distribution maps of the albacore fleet, albacore mostly distributed in subtropical and temperate waters of the South Atlantic Ocean. After confirmation operating distribution of the albacore fleet from logbooks, thus it can supplement the core albacore sampling area which is applied to the task2 data.

For elucidating geographical distribution characteristics of South Atlantic albacore resource, dating from 1967 to 2016, for each decadal period of geographic distribution map of averaging nominal albacore CPUE in weight was shown in Figure 8. As shown in Figure 8, a 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 Ocean. The same pattern was also observed in Figures 9-12, which was obtained exactly the same procedure used to obtain Figure 8. In Figure 2a, Figure 2b and Figures 3-12, the area (10°S-45°S/55°W-20°E excepting for 10°S-15°S/10°W-15°E) was proposed as the core albacore sampling area (Figure 13). These figures showed the core albacore sampling area located in subtropical and temperate waters of the South Atlantic Ocean was always the most dominate fishing ground of albacore by Taiwanese longline fishery.

3.2 Standardization CPUE

A constant 35.7467228, which was obtained by averaging all Taiwanese longliners' nominal albacore CPUE reported from 1967 to 2016 in the core albacore sampling area of the South Atlantic Ocean and divided by 10.

To divide appropriately the South Atlantic albacore's entire habitat into subareas was one of the attempts used in present study for providing corrections stemmed from area contrast. 89 subareas (Figure 13), by 5° latitude x 5° longitude, were thus used in present study based on Taiwanese longline catch statistics.

The ANOVA tables in the core albacore sampling area, as shown in Tables 2-3, which were provided by SAS solver, indicated that (1) factors assigned both in yearly model and in quarter-series model were statistically significant; (2) factors of year/quarter-series and subarea played the most important roles in explanation of its orthogonal variation to the total; (3) the determination coefficient R-square approached 27% in both cases indicated the explanatory resultant by the two models were significant.

In the core albacore sampling area, the yearly nominal CPUE trend and its respective yearly standardized CPUE series thus obtained were tabulated in Table 4 and plotted in Figure 14. The yearly standardized CPUE series showed a continuous decline from the beginning of the Taiwanese longline fishery to 1990, then increased till mid-1990s, and leveled off since early 2000s up to 2016. The normalized residual pattern from this model was shown in Figure 15. As shown in Figure 15, main distribution of residuals ranged from –1.65 to +1.65 and obviously centered at zero as mode. The Q-Q plot of those residuals was also shown in Figure 16 indicating the fitting was not far from normal distribution.

In the core albacore sampling area, the quarterly nominal CPUE trend and its respective quarterly standardized CPUE series thus obtained were tabulated in Table 5 and plotted in Figure 17. The quarterly standardized CPUE series showed a continuous decline from late 1960s to 1990 with higher fluctuation, then increased till mid-1990s, and leveled off since early 2000s up to 2016. The trend appeared in quarterly CPUE series was very similar with those obtained in yearly CPUE trend. Although quarterly trend having more fluctuations, it was very interesting to point out that every four quarters always appeared a high peak strongly implied that a consistent recruitment may have coming in every year. The normalized residual pattern from this model was shown in Figure 18. As shown in Figure 18, main distribution of residuals also ranged from –1.65 to +1.65 and obviously centered at zero as mode. The Q-Q plot of those residuals was shown in Figure 19 indicating the fitting was not far from normal distribution.

IV. DISCUSSION

Comparisons were made visually as in Figure 14 and Figure 17 among the yearly and quarterly nominal CPUE series respectively, which were calculated in the core albacore sampling area and in whole areas [5]. They were similar to those in whole areas of the South Atlantic Ocean from 1976 to 1989. However, the series revealed a different tendency with those in whole areas since early 1990s. The new fishing managements inevitably affected an understanding status of the stock, as compared to those collected through traditional setup. The proposed core albacore sampling area appeared their own significance in this regard.

The proposed core albacore sampling area (Figure 13) was the main fishing ground of albacore for Taiwanese longline fishery, had own characteristics and represented meaning. The core albacore sampling area was proposed mainly for minimizing those non-albacore-targeting noises. We hope, through such manipulations, give a more persuasive resultant CPUE trend than current endeavors.

ACKNOWLEDGMENTS

We are grateful for the Fisheries Agency and Overseas Fisheries Development Council of Taiwanese fisheries managerial sectors for their financial supports and tremendous efforts devoted to fisheries catch and effort statistical data collection and compilation.

REFERENCES

[1]. ICCAT, *Report of the bluefin tuna methodology session,* 1996.
[2]. S. Gavaris, Use of a multiplicative model to estimate catch rate and effort from commercial data. *Can. J. Fish. Aquat. Sci., 37,* 1980, 2272-2275.
[3]. D. K. Kimura, Standardized measures of relative abundance based on modeling log(CPUE), and their application to Pacific Ocean perch *(Sebastes alutus)*, *J. Cons. Int. Explore, Mer., 39,* 1981, 211-218.
[4]. D. S. Robson, Estimation of the relative fishing power of individual ships. *ICNAF Res. Bull., 3,* 1996, 5-15.
[5]. F. C. Chang and S. Y. Yeh, CPUE standardization, using proper albacore subareas and dating from 1967 to 2013, on albacore caught by Taiwanese longliners fishing in the South Atlantic Ocean. *Collect. Vol. Sci. Pap. ICCAT, 71(5),* 2015, 2438-2457.

Table 1: The result of cluster analysis based on the logbook catches in weight (kg) of albacore, bigeye tuna, yellowfin tuna and swordfish from 1981 to 2016.

cluster	ALB_wt	BET_wt	YFT_wt	SWO_wt
1	61,187	1,081	728	461
2	2,512	6,273	1,253	647
3	27,718	1,018	696	408
4	344	25,994	2,013	1,277

Remark: ALB: Albacore, BET: Bigeye tuna, YFT: Yellowfin tuna, and SWO: Swordfish.

Table 2: Analysis of variance on standardizing South Atlantic albacore (in the core albacore sampling area) yearly CPUE using Taiwanese longline fishery task2 data set from 1967 to 2016 by the GLM procedure.

Dependent Variable: Logcpuew_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	140	1537.63026	10.98307	30.14	<.0001
Error	10978	4000.60072	0.36442		
Corrected Total	11118	5538.23097			

R-Square	Coeff Var	Root MSE	Logcpuew_alb Mean
0.27764	10.46450	0.60367	5.76876

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	49	730.23543	14.90276	40.89	<.0001
quarter	3	78.79869	26.26623	72.08	<.0001
subarea	88	614.41161	6.98195	19.16	<.0001

Table 3: Analysis of variance on standardizing South Atlantic albacore (in the core albacore sampling area) quarterly CPUE using Taiwanese longline fishery task2 data set from 1967 to 2016 by the GLM procedure.

Dependent Variable: Logcpuew_alb

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	285	1818.63686	6.38118	18.58	<.0001
Error	10833	3719.59411	0.34336		
Corrected Total	11118	5538.23097			

R-Square	Coeff Var	Root MSE	Logcpuew_alb Mean
0.32838	0.32838	0.58597	5.76876

Source	DF	Type III SS	Mean Square	F Value	Pr > F
yq	197	1075.30185	5.45839	15.90	<.0001
subarea	88	586.74973	6.66761	19.42	<.0001

Table 4: Yearly nominal and standardized CPUE trends of the core South Atlantic albacore sampling area based on Taiwanese longline fishery task2 data set from 1967 to 2016 by the GLM procedure.

Year	Nominal CPUE	Standardized CPUE	CV
1967	876.12	837.86	0.0447
1968	1161.02	647.46	0.0116
1969	812.47	604.68	0.0073
1970	682.97	493.40	0.0068
1971	814.97	546.36	0.0074
1972	565.58	353.16	0.0073
1973	455.21	294.02	0.0089
1974	484.84	317.77	0.0072
1975	560.29	357.63	0.0078
1976	391.12	330.65	0.0068
1977	528.10	388.58	0.0063
1978	501.49	357.40	0.0060
1979	444.41	333.15	0.0069
1980	493.29	347.73	0.0062
1981	436.82	330.66	0.0063
1982	424.66	319.39	0.0059
1983	405.34	298.70	0.0073
1984	489.47	364.55	0.0084
1985	407.33	316.14	0.0068
1986	427.68	309.16	0.0061
1987	337.09	256.81	0.0064
1988	284.41	200.00	0.0089
1989	268.38	163.01	0.0096
1990	282.27	174.14	0.0095
1991	275.30	199.21	0.0081
1992	320.15	217.44	0.0098
1993	289.59	218.19	0.0076
1994	342.95	264.86	0.0073
1995	376.64	257.18	0.0075
1996	491.08	257.17	0.0071
1997	473.56	310.56	0.0068
1998	432.21	277.33	0.0077
1999	301.75	199.23	0.0062
2000	272.01	171.21	0.0060
2001	303.86	225.82	0.0068
2002	268.87	159.31	0.0069
2003	248.92	144.51	0.0095
2004	357.31	184.35	0.0126
2005	297.56	243.97	0.0069
2006	286.69	221.47	0.0065
2007	444.90	262.13	0.0071
2008	437.01	260.96	0.0076
2009	449.35	277.88	0.0075
2010	457.39	298.02	0.0074
2011	376.53	254.60	0.0073
2012	416.80	258.14	0.0076
2013	376.86	264.05	0.0074
2014	350.93	203.28	0.0078
2015	458.00	276.12	0.0076
2016	449.14	324.95	0.0075

Table 5: Quarterly nominal and standardized CPUE trends of the core South Atlantic albacore sampling area based on Taiwanese longline fishery task2 data set from 1967 to 2016 by the GLM procedure.

Year*Quarter	Nominal CPUE	Standardized CPUE	CV
19673	969.25	967.13	0.0491
19674	469.32	603.33	0.0910
19681	731.14	345.66	0.0404
19682	1439.22	1382.30	0.0210
19683	1130.51	908.88	0.0158
19684	304.69	217.05	0.0275
19691	767.50	494.31	0.0193
19692	1075.97	651.52	0.0163
19693	837.83	690.09	0.0123
19694	630.84	550.63	0.0117
19701	698.52	438.78	0.0150
19702	1061.47	676.45	0.0165
19703	848.26	641.28	0.0114
19704	381.39	351.34	0.0112
19711	436.46	413.97	0.0155
19712	1234.23	917.27	0.0146
19713	1054.77	763.43	0.0128
19714	389.48	341.69	0.0135
19721	525.11	392.32	0.0163
19722	713.26	519.61	0.0139
19723	594.23	371.64	0.0117
19724	260.74	227.41	0.0146
19731	439.68	254.01	0.0179
19732	641.93	536.36	0.0168
19733	490.08	341.54	0.0164
19734	227.35	181.10	0.0167
19741	370.90	233.14	0.0164
19742	609.92	405.59	0.0119
19743	591.21	398.99	0.0120
19744	284.51	238.15	0.0154
19751	494.28	340.89	0.0171
19752	808.58	593.47	0.0149
19753	612.42	379.48	0.0123
19754	268.37	223.99	0.0163
19761	356.71	284.23	0.0143
19762	521.05	468.94	0.0120
19763	421.98	390.73	0.0118
19764	213.21	226.94	0.0134
19771	451.37	374.08	0.0124
19772	663.00	592.08	0.0122
19773	557.74	375.04	0.0108
19774	329.45	301.69	0.0122
19781	448.62	301.69	0.0112
19782	607.83	483.04	0.0103
19783	500.26	351.13	0.0113
19784	344.33	322.99	0.0124
19791	419.13	320.66	0.0127
19792	546.60	387.39	0.0134
19793	420.36	333.51	0.0132
19794	319.24	299.14	0.0131
19801	506.18	349.87	0.0120
19802	671.96	494.65	0.0122
19803	450.77	295.78	0.0108
19804	334.77	314.60	0.0114
19811	467.99	374.62	0.0113
19812	485.02	379.16	0.0123
19813	399.84	298.04	0.0110
19814	387.43	293.92	0.0140
19821	442.43	337.65	0.0106
19822	499.96	371.33	0.0109
19823	369.84	322.84	0.0100
19824	342.86	253.09	0.0140
19831	346.86	241.94	0.0118
19832	440.75	312.88	0.0150
19833	432.26	327.89	0.0140
19834	442.61	385.99	0.0161
19841	508.75	379.32	0.0179
19842	658.36	469.10	0.0159
19843	394.84	322.95	0.0152
19844	463.06	331.50	0.0152
19851	393.47	293.30	0.0124
19852	457.47	378.73	0.0134
19853	390.02	308.43	0.0119
19854	361.83	310.85	0.0140
19861	430.22	315.41	0.0109
19862	503.80	369.61	0.0111
19863	391.93	317.36	0.0113
19864	316.93	246.76	0.0126
19871	368.78	285.09	0.0112
19872	370.90	289.06	0.0118
19873	283.07	228.24	0.0125
19874	296.47	228.91	0.0124
19881	258.79	178.68	0.0126
19882	297.02	244.09	0.0178
19883	233.74	179.38	0.0181
19884	409.74	292.15	0.0274
19891	366.84	198.65	0.0198
19892	252.81	157.09	0.0170
19893	227.90	189.27	0.0182
19894	234.44	135.73	0.0180
19901	286.80	186.25	0.0162
19902	330.26	225.34	0.0168
19903	233.79	164.14	0.0164
19904	295.00	114.61	0.0295
19911	276.92	220.35	0.0159
19912	261.52	178.80	0.0147
19913	262.00	211.82	0.0152
19914	303.81	205.28	0.0155
19921	291.79	201.94	0.0185
19922	347.26	286.55	0.0166
19923	328.77	239.33	0.0178
19924	290.66	141.27	0.0238
19931	258.01	127.89	0.0200
19932	341.38	276.06	0.0159
19933	297.48	201.65	0.0154
19934	274.46	232.13	0.0112
19941	373.27	290.61	0.0126
19942	399.73	293.67	0.0141
19943	259.81	221.34	0.0138
19944	282.21	265.46	0.0152
19951	417.16	300.42	0.0196
19952	441.72	313.88	0.0141
19953	303.10	203.55	0.0129
19954	402.50	269.88	0.0125
19961	621.92	268.40	0.0138
19962	466.21	275.53	0.0122
19963	371.09	231.96	0.0127
19964	575.60	283.17	0.0147
19971	563.33	291.77	0.0117
19972	490.10	325.15	0.0134
19973	395.54	329.53	0.0140
19974	462.04	299.17	0.0124
19981	398.30	304.51	0.0146
19982	546.59	350.22	0.0143
19983	442.28	302.20	0.0139
19984	286.62	188.35	0.0152
19991	239.85	168.61	0.0114
19992	342.63	184.26	0.0124
19993	311.05	228.56	0.0107
19994	302.11	217.35	0.0117
20001	240.88	150.97	0.0109
20002	316.58	174.50	0.0105
20003	246.58	175.45	0.0116
20004	278.79	202.53	0.0123
20011	323.10	250.45	0.0110
20012	302.30	172.12	0.0136
20013	310.99	256.55	0.0133
20014	271.85	225.68	0.0143
20021	277.34	202.41	0.0115
20022	270.07	139.80	0.0126
20023	235.80	143.89	0.0122
20024	316.33	179.08	0.0179
20031	246.67	163.38	0.0165
20032	267.73	147.03	0.0166
20033	226.88	190.34	0.0185
20034	251.05	89.24	0.0220
20041	221.07	163.86	0.0204
20042	650.64	246.81	0.0315
20043	396.83	265.69	0.0203
20044	333.96	82.93	0.0319
20051	257.32	211.09	0.0119
20052	353.62	241.85	0.0144
20053	331.64	271.97	0.0125
20054	256.45	257.43	0.0140
20061	287.94	221.16	0.0115
20062	342.66	254.31	0.0125
20063	258.20	257.01	0.0120
20064	217.40	162.06	0.0132
20071	284.98	181.33	0.0134
20072	636.67	401.53	0.0134
20073	474.87	344.57	0.0127
20074	271.10	196.36	0.0139
20081	335.81	253.52	0.0141
20082	516.50	317.23	0.0131
20083	444.73	290.68	0.0124
20084	279.31	163.04	0.0215
20091	343.56	240.32	0.0135
20092	489.53	278.44	0.0137
20093	547.90	394.89	0.0136
20094	290.94	228.38	0.0168
20101	347.26	246.10	0.0129
20102	490.28	299.84	0.0138
20103	513.72	430.04	0.0131
20104	463.42	249.19	0.0180
20111	353.83	254.08	0.0128
20112	429.09	341.30	0.0135
20113	359.10	240.85	0.0123
20114	304.98	196.42	0.0177
20121	419.35	200.77	0.0142
20122	420.29	297.38	0.0128
20123	464.71	352.70	0.0146
20124	283.40	220.11	0.0163
20131	352.10	191.90	0.0158
20132	419.02	320.70	0.0140
20133	367.52	302.87	0.0133
20134	359.40	248.50	0.0132
20141	249.82	136.08	0.0152
20142	408.06	213.92	0.0158
20143	340.50	238.59	0.0128
20144	356.63	254.71	0.0156
20151	321.04	190.21	0.0152
20152	499.11	256.79	0.0145
20153	427.93	375.42	0.0133
20154	587.00	320.66	0.0149
20161	314.04	205.54	0.0153
20162	478.23	349.30	0.0140
20163	482.40	339.35	0.0138
20164	541.72	454.58	0.0137

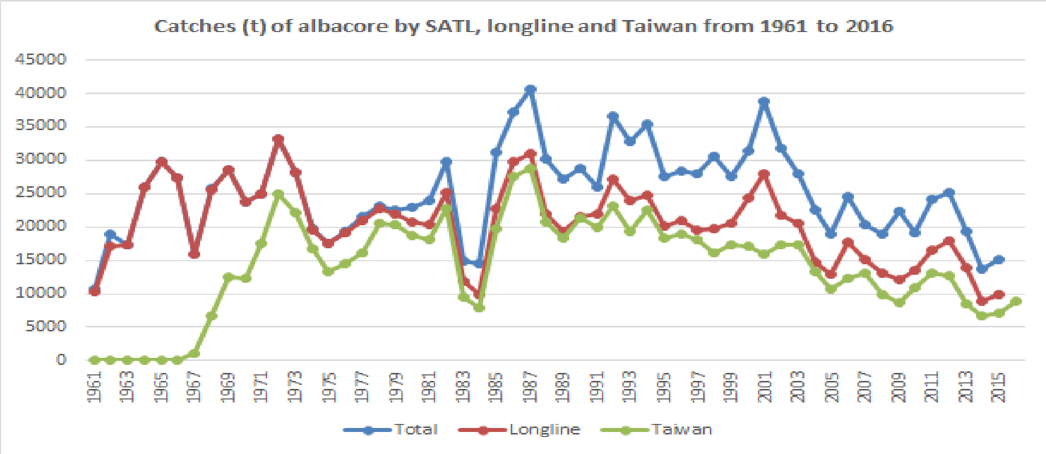

Figure 1: Historical albacore catch of Taiwanese longline fishing vessels in the South Atlantic Ocean, 1961-2016. Sources: ICCAT (task1) and OFDC.

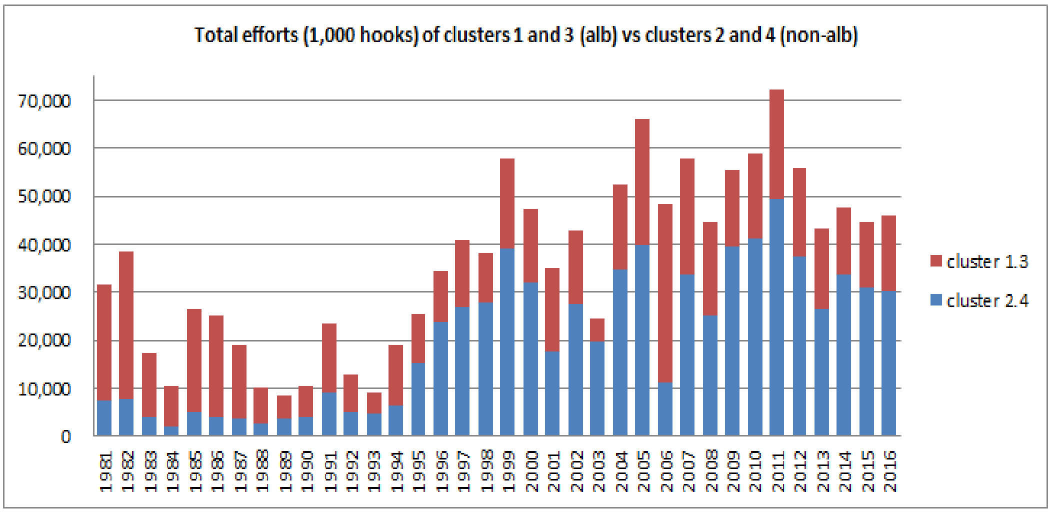

Figure 2a: Total efforts (1,000 hooks) by Taiwanese longliners operated in cluster 1 and cluster 3 targeting albacore v.s. in cluster 2 and cluster 4 targeting non-albacore of the South Atlantic Ocean from 1981 to 2016.

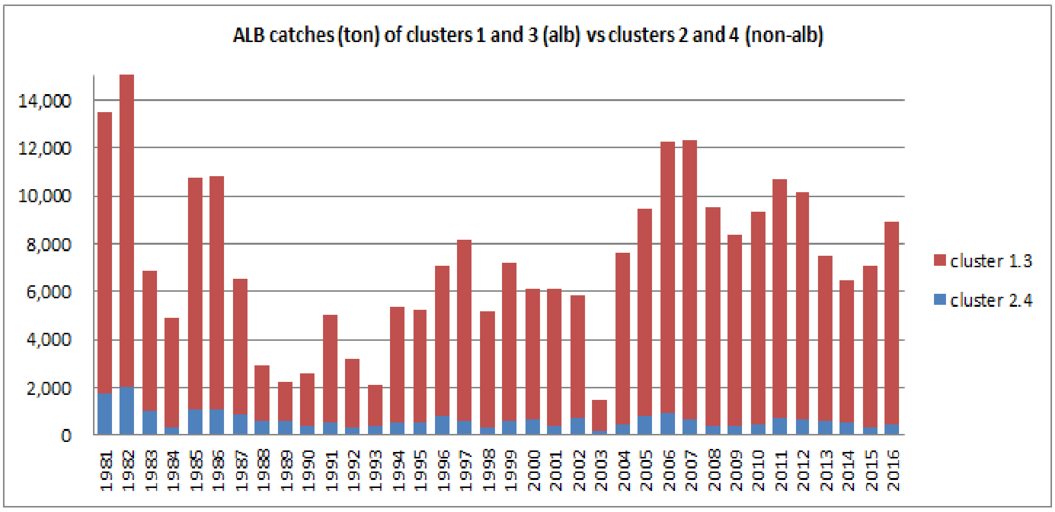

Figure 2b: Albacore catches (ton) by Taiwanese longliners operated in cluster 1 and cluster 3 targeting albacore v.s. in cluster 2 and cluster 4 targeting non-albacore of the South Atlantic Ocean from 1981 to 2016.

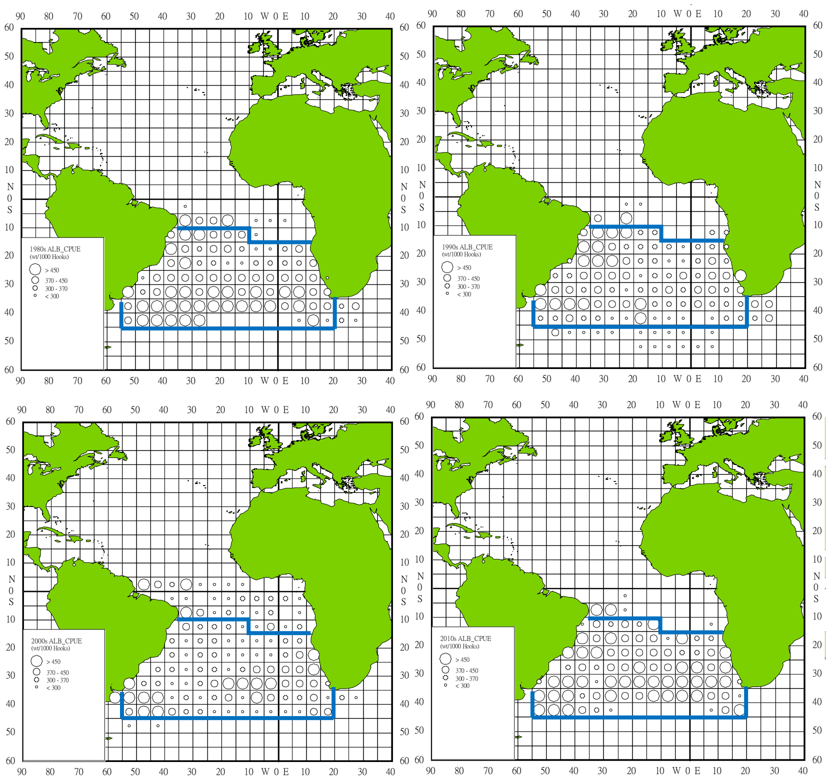

Figure 3: Yearly nominal CPUE (Wt./1000 Hooks from logbook) of albacore caught by Taiwanese longliners in the South Atlantic Ocean for periods of 1980-1989 (Upper-Left), 1990-1999 (Upper-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right).

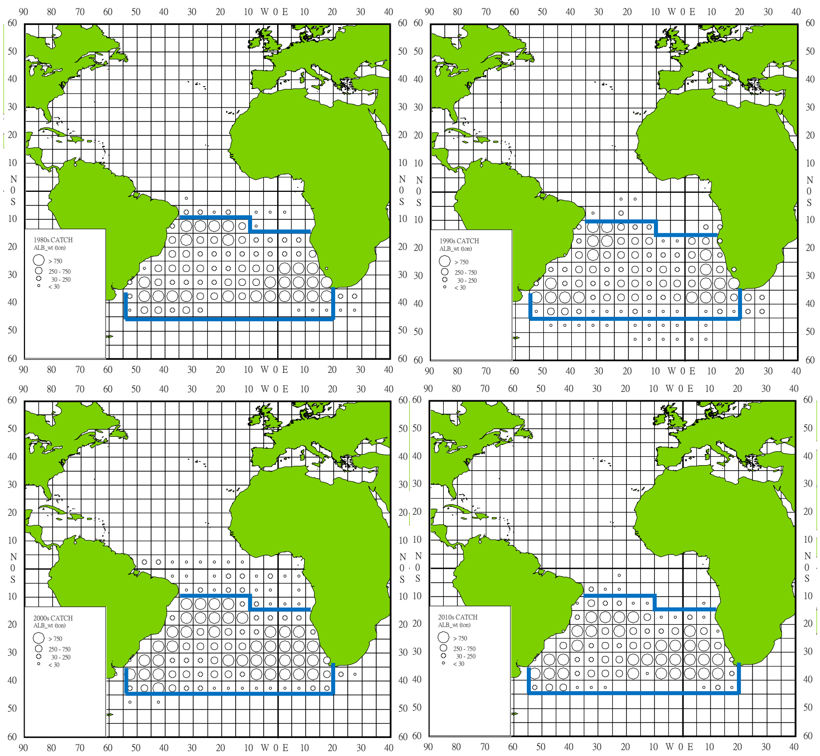

Figure 4: Geographic distribution, by 5°-square block, of catch in weight (from logbooks) of albacore caught by Taiwanese longliners in the South Atlantic Ocean for periods of 1981-1989 (Upper-Left), 1990-1999 (Upper-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right).

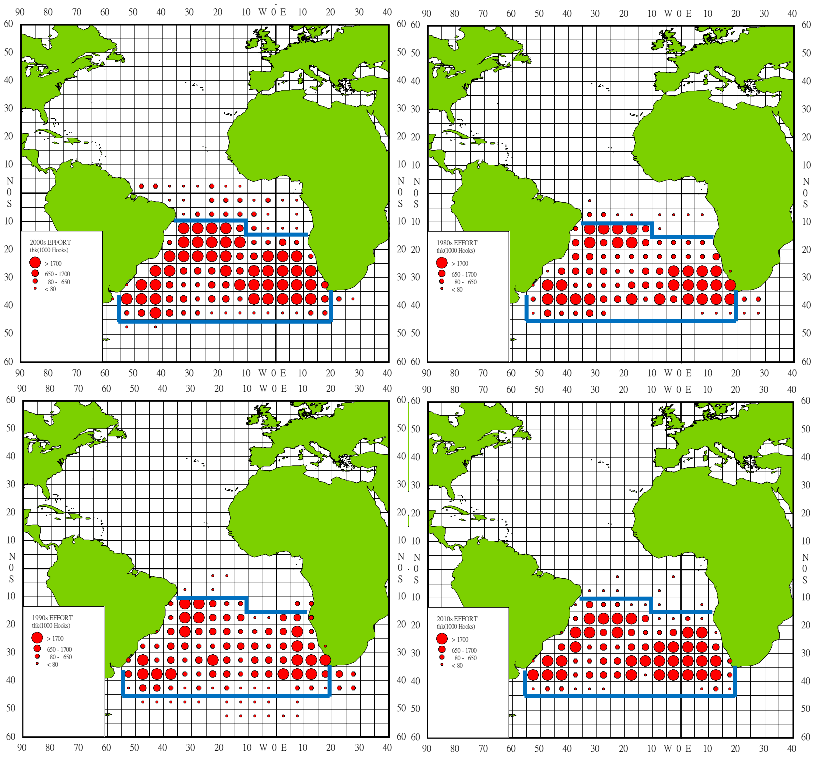

Figure 5: Geographic distribution, by 5°-square block, of the fishing efforts (Number of 1,000 hooks from logbooks) cast by Taiwanese longliners in the South Atlantic Ocean for periods of 1981-1989 (Upper-Left), 1990-1999 (Upper-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right).

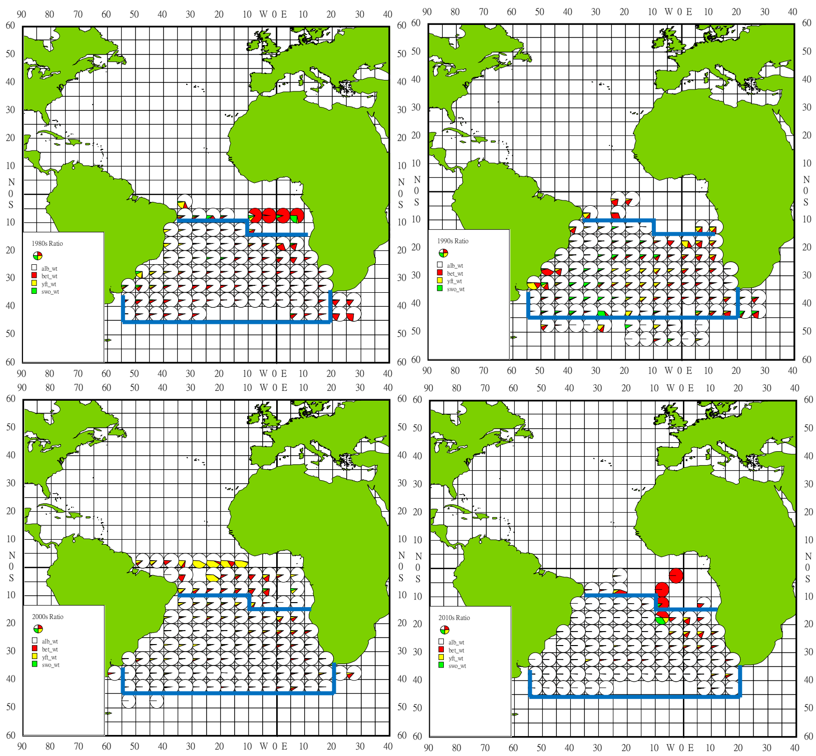

Figure 6: Geographic distribution, by 5°-square block, of four major species composition, in terms of catch in weight (from logbooks), caught by Taiwanese longliners in the South Atlantic Ocean for periods of 1981-1989 (Upper-Left), 1990-1999 (Upper-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right). Four major species are: albacore (ALB in white), bigeye tuna (BET in red), yellowfin tuna (YFT in yellow) and swordfish (SWO in green).

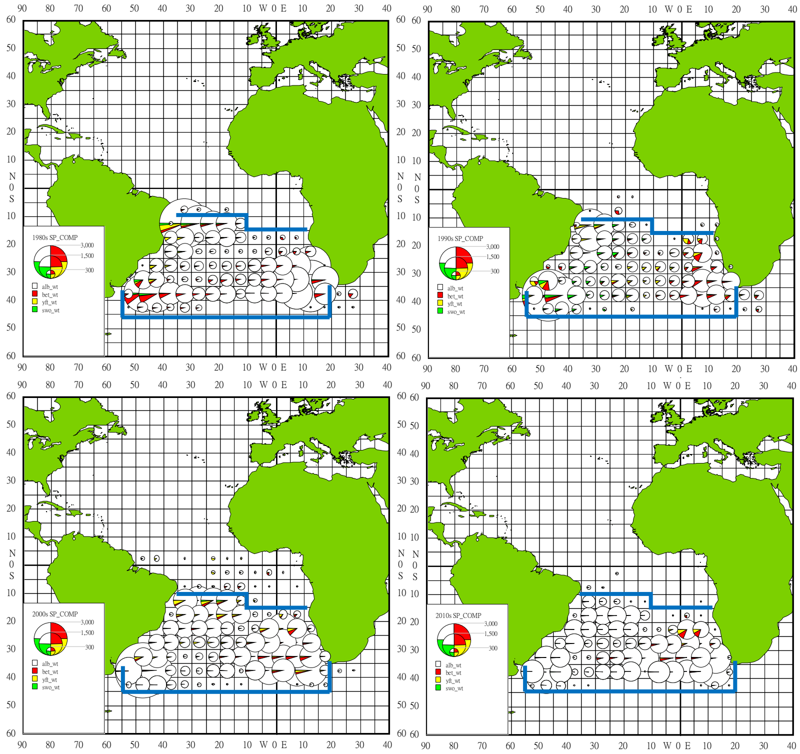

Figure 7: Geographic distribution, by 5°-square block, of catch in weight of four major species (from logbooks), caught by Taiwanese longliners in the South Atlantic Ocean for periods of 1981-1989 (Upper-Left), 1990-1999 (Upper-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right). Four major species are: albacore (ALB in white), bigeye tuna (BET in red), yellowfin tuna (YFT in yellow) and swordfish (SWO in green).

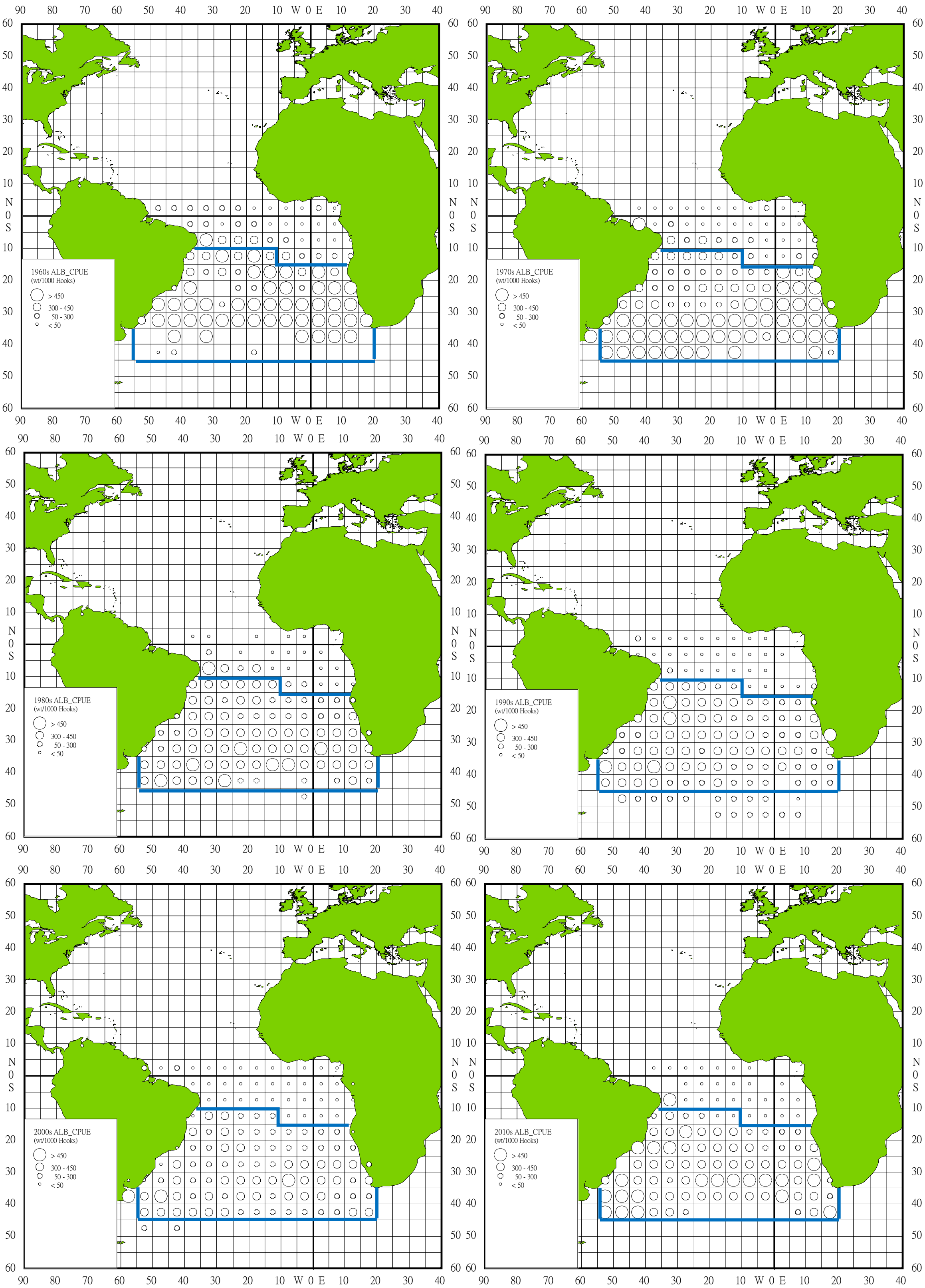

Figure 8: Yearly nominal CPUE (Wt./1000 Hooks from task2) of albacore caught by Taiwanese longliners in the South Atlantic Ocean for periods of 1967-1969 (Upper-Left), 1970-1979 (Upper-Right), 1980-1989 (Mid-Left), 1990-1999 (Mid-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right).

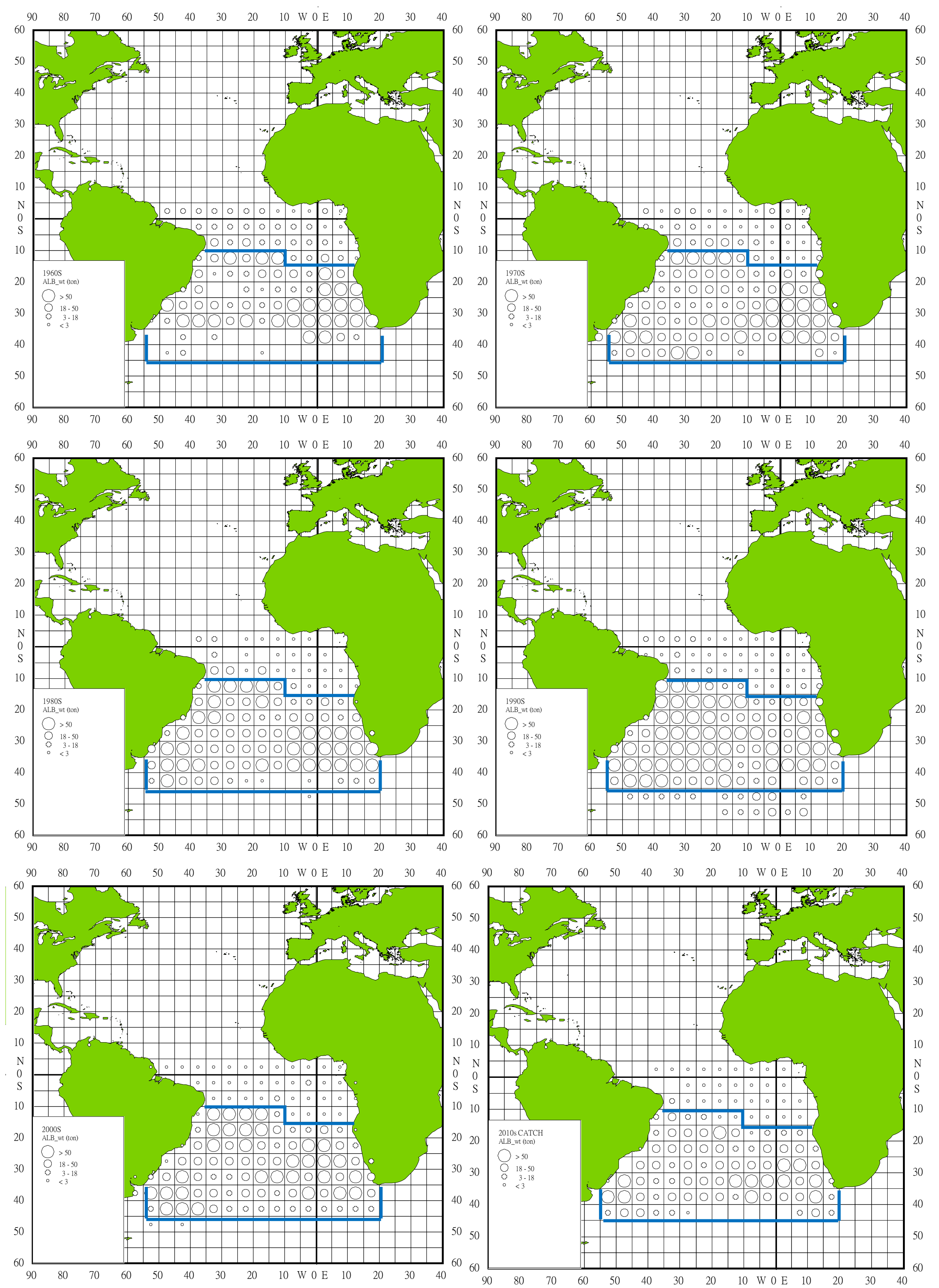

Figure 9: Yearly catch in weight (from task2) of albacore caught by Taiwanese longliners in the South Atlantic Ocean for periods of 1967-1969 (Upper-Left), 1970-1979 (Upper-Right), 1980-1989 (Mid-Left), 1990-1999 (Mid-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right).

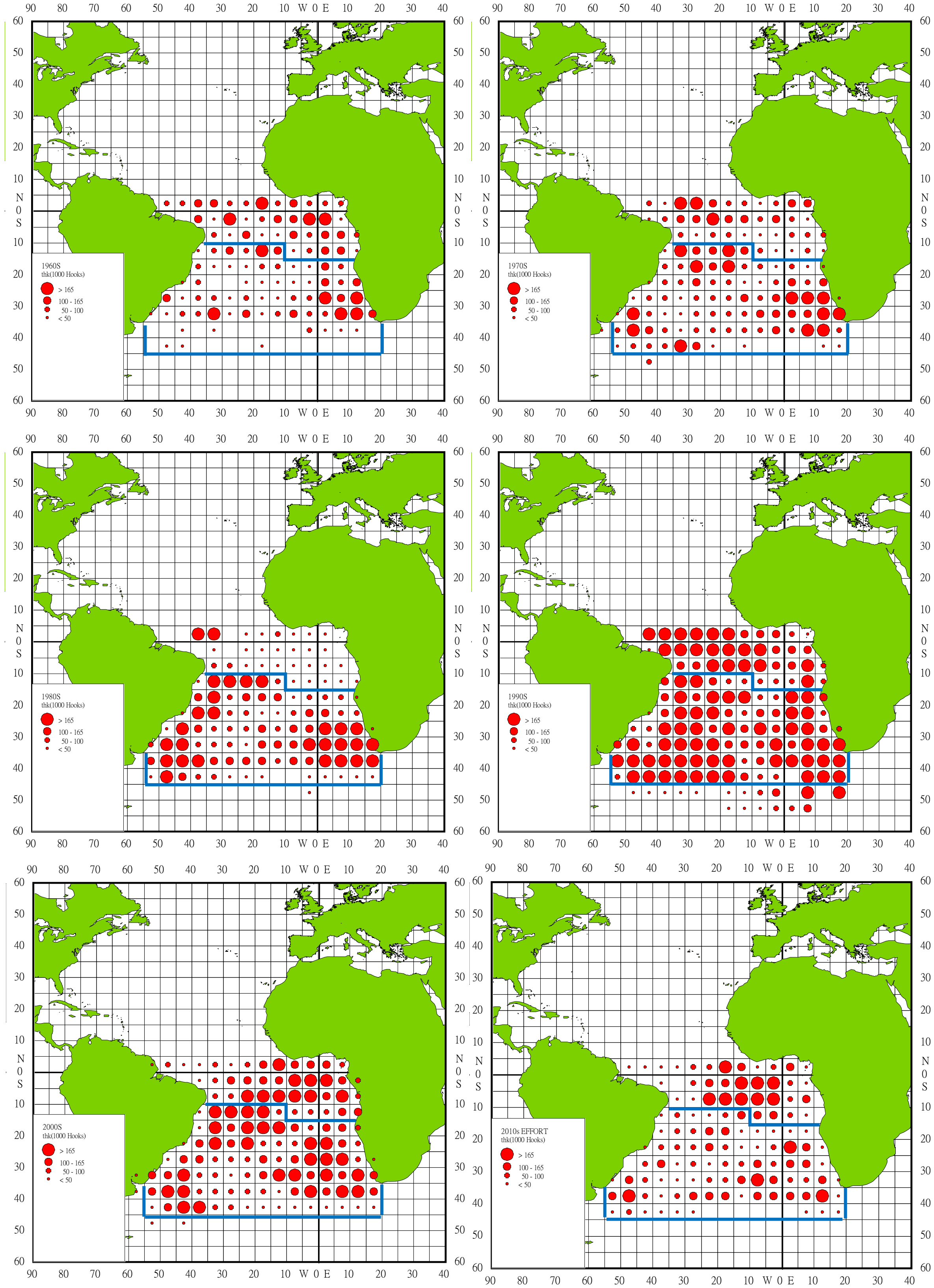

Figure 10: Yearly fishing efforts (Number of hooks from task2) cast by Taiwanese longliners in the South Atlantic Ocean for periods of 1967-1969 (Upper-Left), 1970-1979 (Upper-Right), 1980-1989 (Mid-Left), 1990-1999 (Mid-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right).

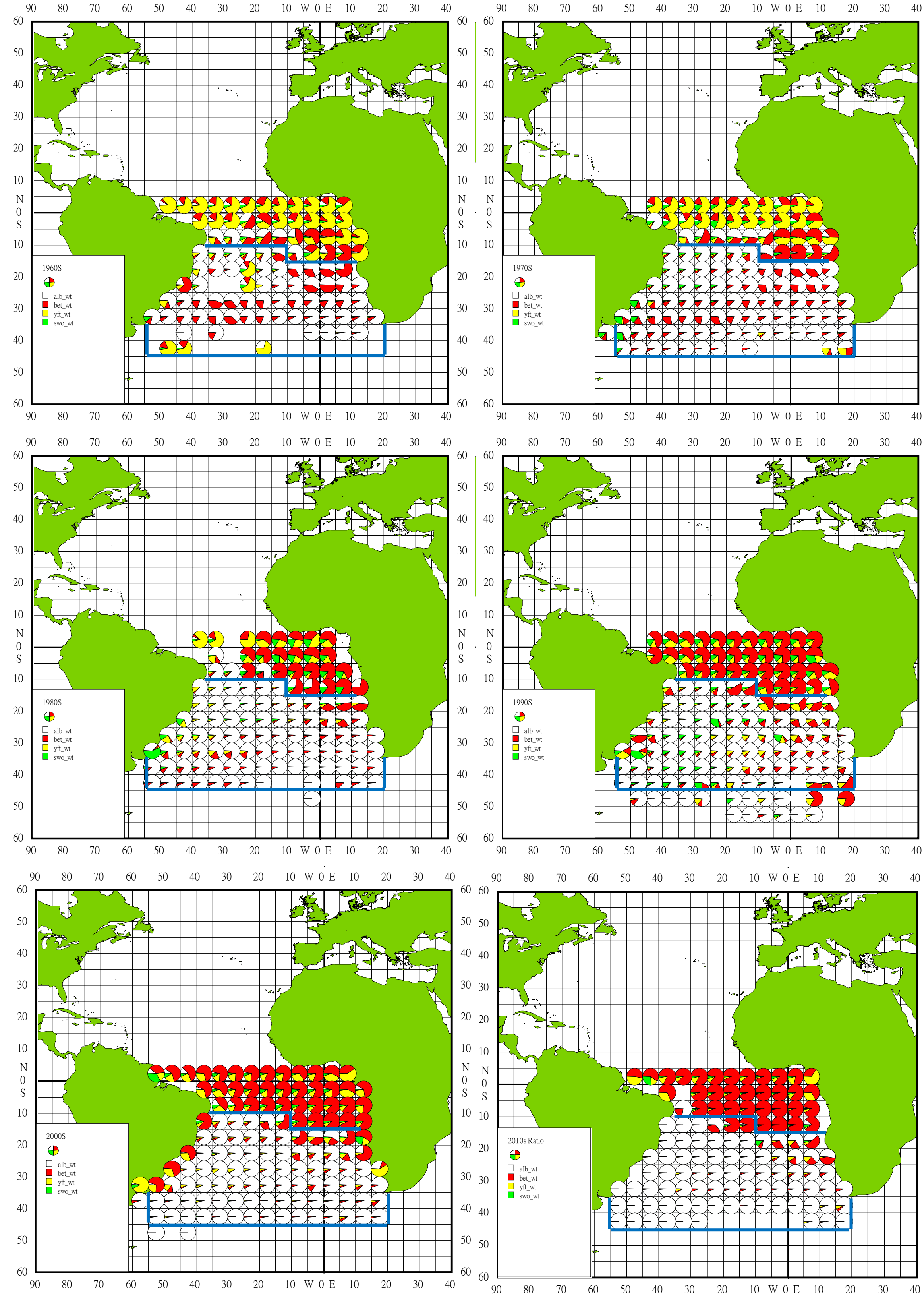

Figure 11: Geographic distribution of yearly four major species composition (from task2) caught by Taiwanese longliners for periods of 1967-1969 (Upper-Left), 1970-1979 (Upper-Right), 1980-1989 (Mid-Left), 1990-1999 (Mid-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right).

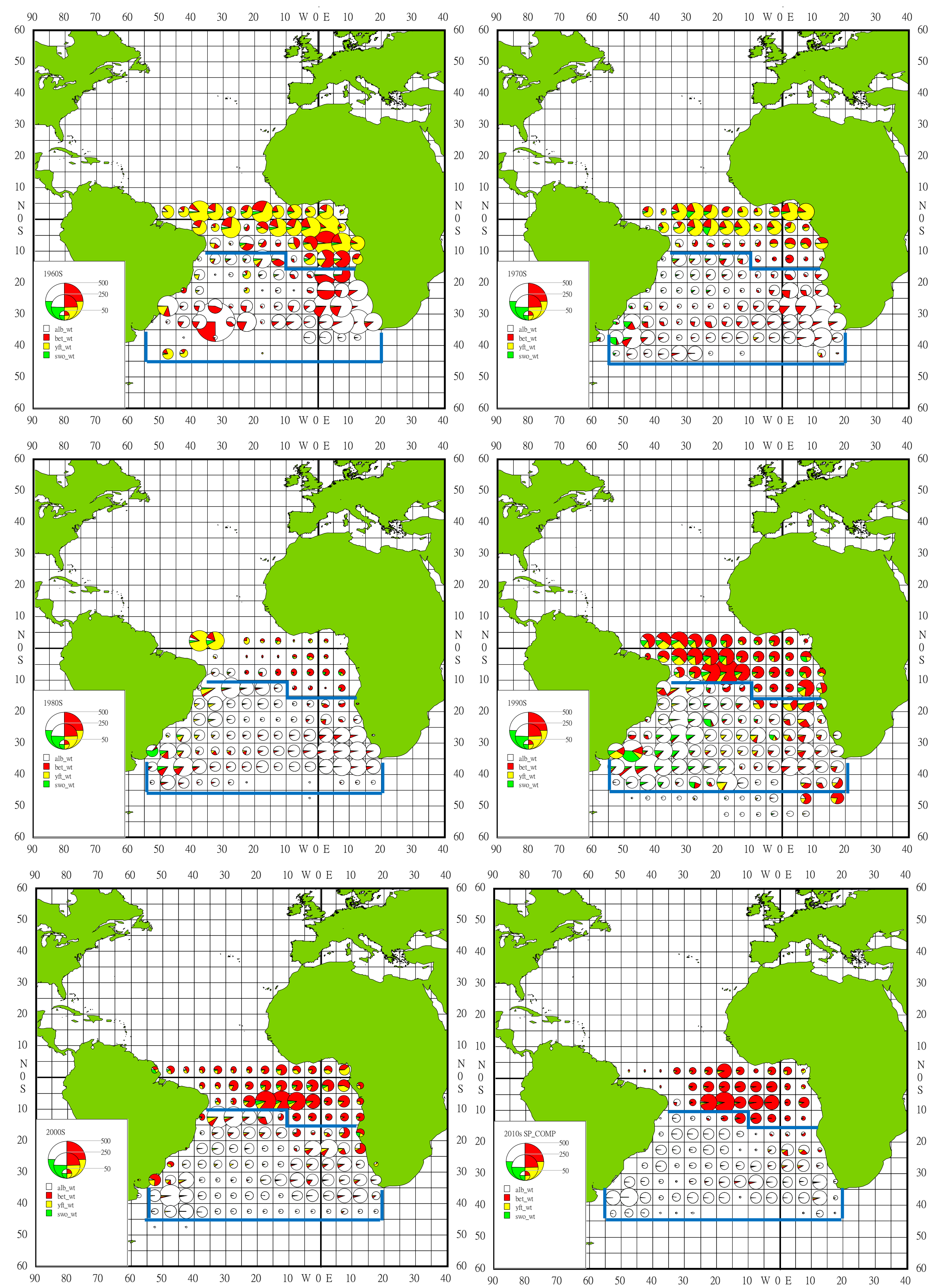

Figure 12: Geographic distribution of yearly catch composition of four major species (from task2) caught by Taiwanese longliners for periods of 1967-1969 (Upper-Left), 1970-1979 (Upper-Right), 1980-1989 (Mid-Left), 1990-1999 (Mid-Right), 2000-2009 (Lower-Left), and 2010-2016 (Lower-Right).

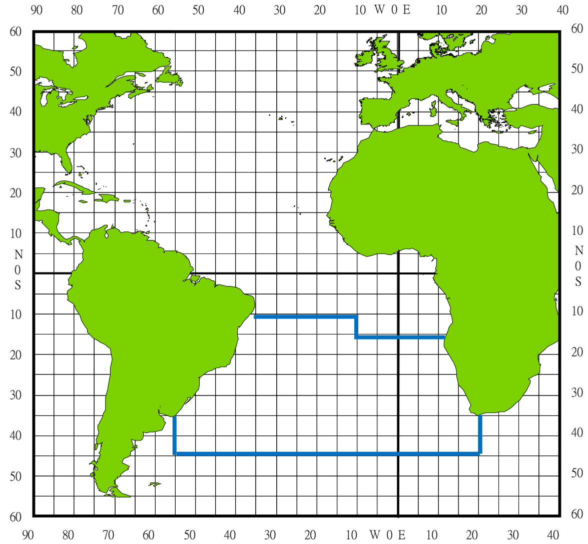

Figure 13: The 89, by 5°-square block, subareas (encircled by blue lines) thus proposed by this paper for CPUE standardization on albacore resource in the South Atlantic Ocean.

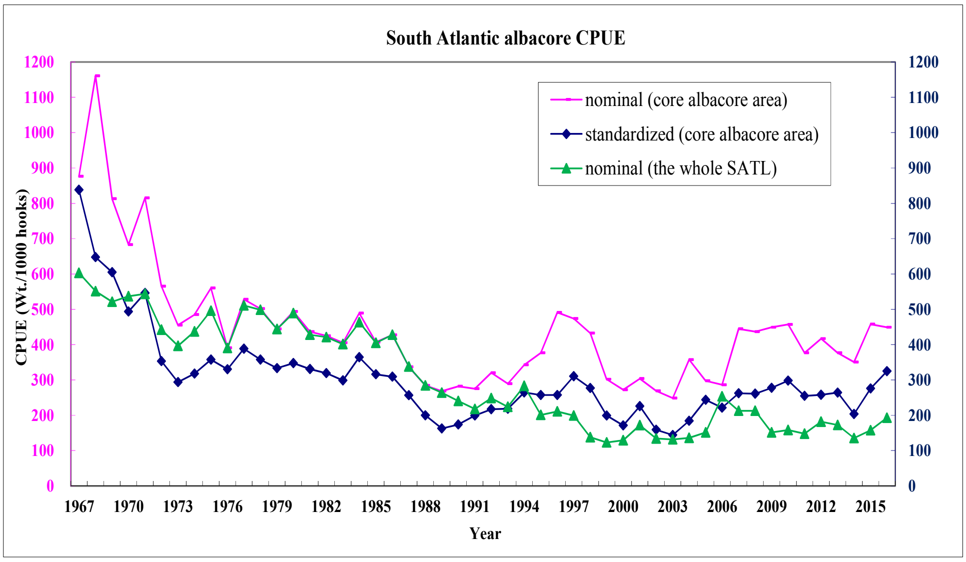

Figure 14: Yearly nominal and standardized CPUE (Wt./1000 Hooks) trends of South Atlantic albacore based on Taiwanese longline fishery task2 data set from 1967 to 2016.

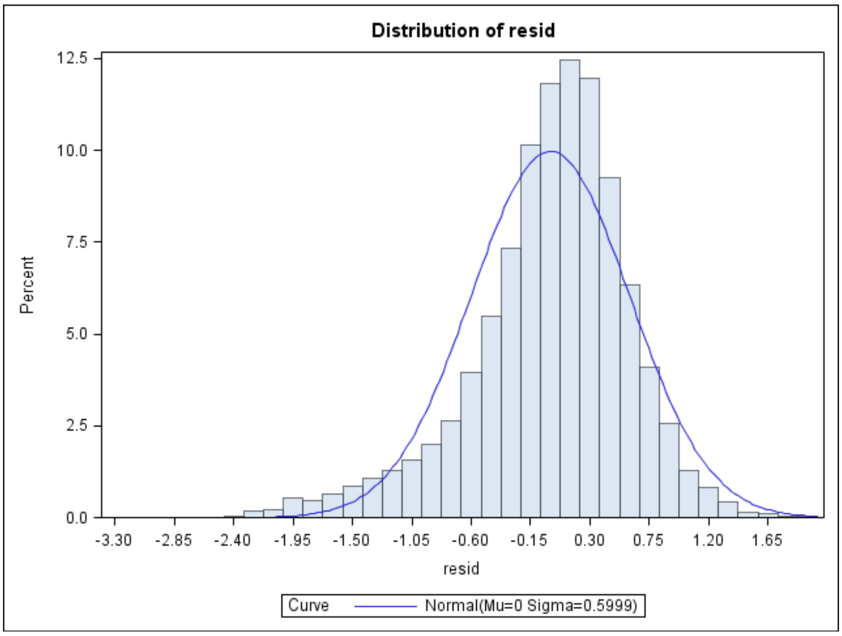

Figure 15: Distribution of normalized residual obtained from yearly GLM model.

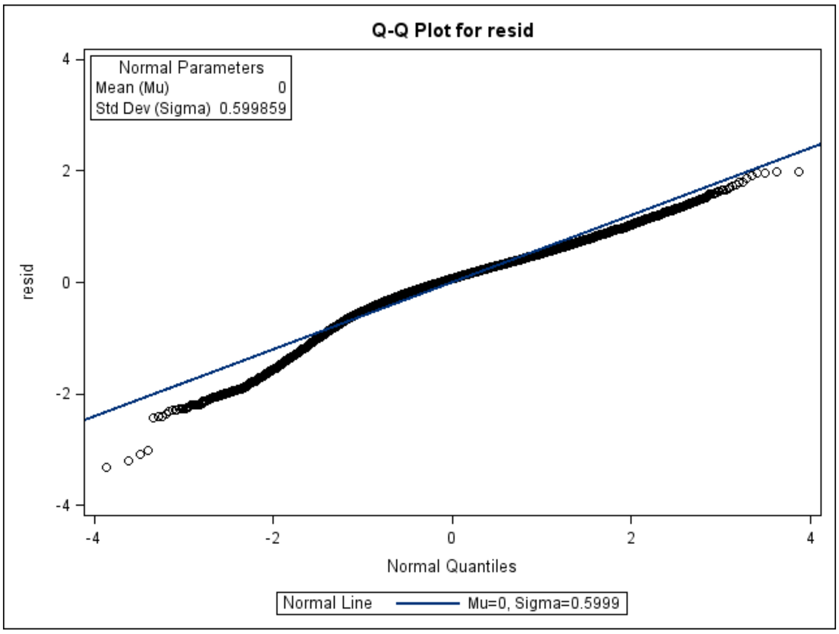

Figure 16: The Q-Q plot for residuals obtained from yearly GLM model.

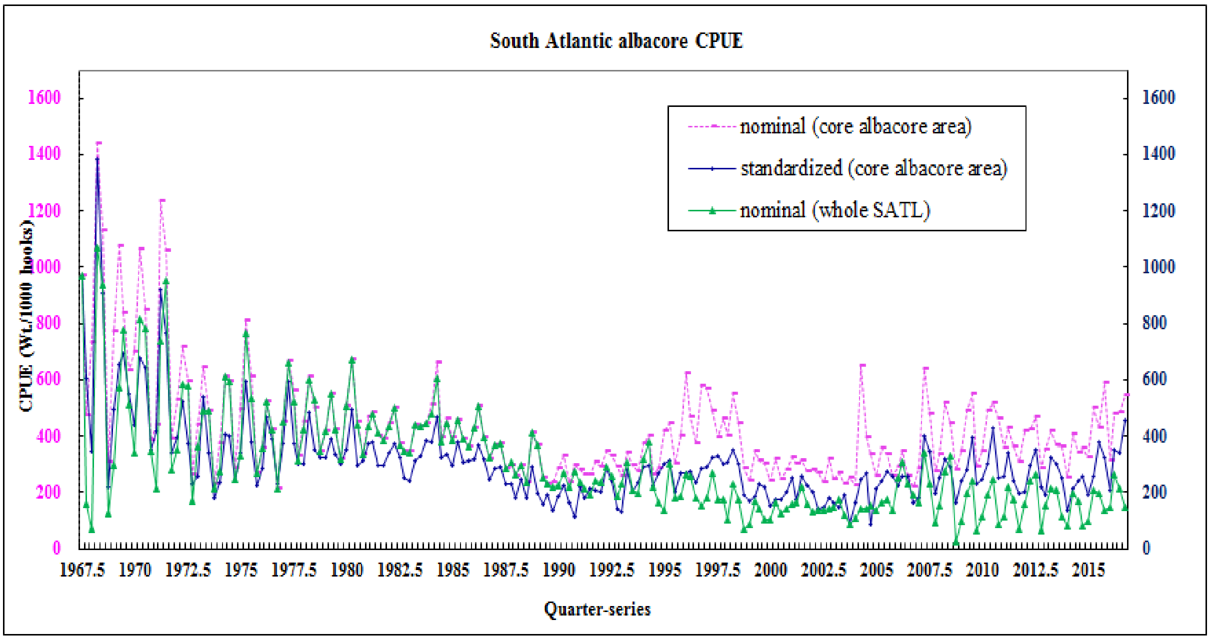

Figure 17: Quarterly nominal and standardized CPUE (Wt./1000 Hooks) trends of South Atlantic albacore based on Taiwanese longline fishery task2 data set from 1967 to 2016.

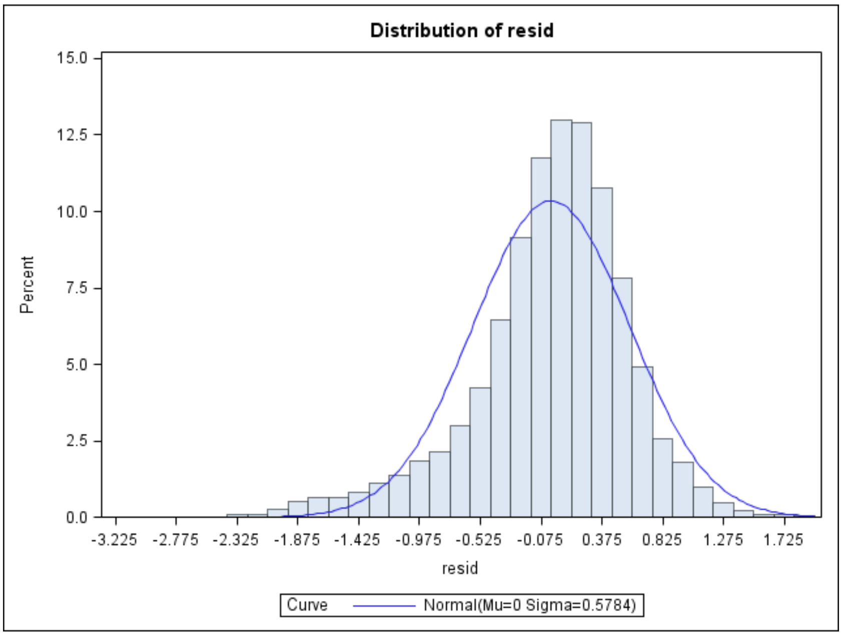

Figure 18: Distribution of normalized residual obtained from quarterly GLM model.

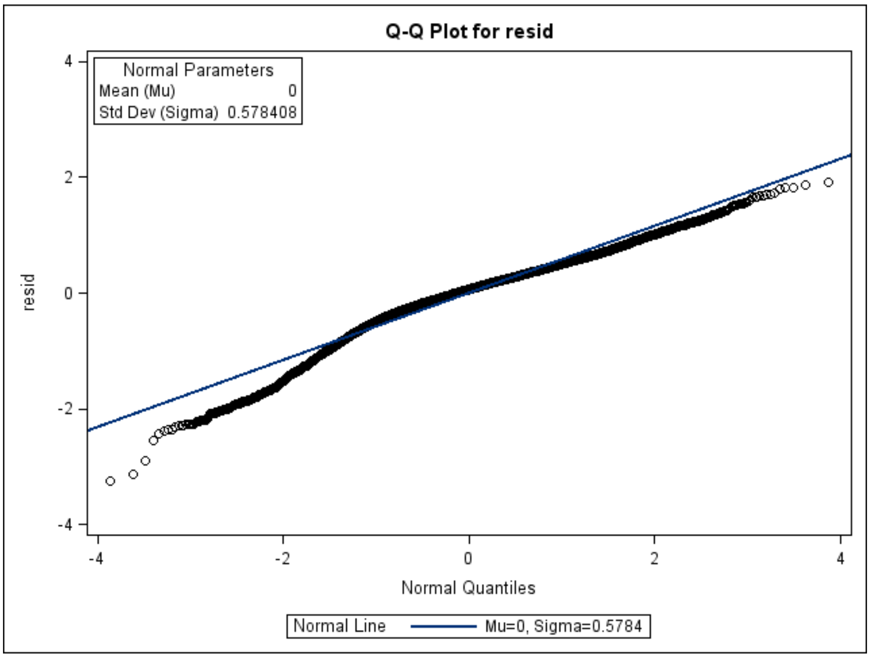

Figure 19: The Q-Q plot for residuals obtained from quarterly GLM model.

Feng-Chen Chang* "CPUE Standardization on Southern Atlantic Albacore, Dating From 1967 to 2016, Based On Catch Statistics of Taiwanese Longliners" International Journal Of Modern Engineering Research (IJMER), vol. 08, no. 01, 2018, pp. 01–21.