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STANDARDIZATION OF CATCH PER UNIT EFFORT AND REVIEW OF TAIWANESE LONGLINE FISHERY FOR BIGEYE TUNA IN THE ATLANTIC

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SUMMARY

Taiwan has become one of the bigeye tuna fishing nations using longline gear in the Atlantic 1990, while the target has shifted from albacore to tropical tunas, and following the Japanese, Taiwan introduced deep longline in the tropical Atlantic recently. In order to capture and regulate the fishery, the present report aims at verifying the historical catch data and trying to use applicable logbook data to standardize the catch rates as an abundance index.

The historical catch data reveal that the Taiwanese caught bigeye tuna as by-catch from the early 1960s to the late 1980s, during which time the highest catches occurred from 1968 to 1975 and then significantly decreased from then on. Bigeye have been taken as target species since 1990. The historical catch records were updated for 1991, 1992 and 1994.

The standardization of abundance indices was done using general linear model (GLM) for aggregated Taiwanese logbook data. Three single effects (year, month and fishing sub-area) were used in the GLM model for 1968-1976, 1975-1988, 1988-1994 and 1968-1994 time periods. The results show that residuals obtained from GLM fits were in less validation for normal error assumption, but no different relative catch per unit effort (CPUE) trend was observed for the four periods. Consequently, the 1968-1994 standardized CPUE was selected for the Taiwanese longline fishery in the total Atlantic. The standardized CPUE series shows a slightly fluctuating decreasing trend from the beginning of the Taiwanese fishery to the lowest in level in 1989, and then increased and its has fluctuated since.

RÉSUMÉ

Taïwan participe depuis 1990 à la pêcherie palangrière de thon obèse dans l'Atlantique, suite à un changement de cible (du germon aux thonidés tropicaux) et à l'instar du Japon, à l'introduction récente de la palangre profonde dans l'Atlantique tropical. Le présent rapport a pour objectif de vérifier les données historiques de capture et d'utiliser les données applicables des carnets de pêche pour standardiser les taux de capture en indices d'abondance.

Les données historiques de capture indiquent que les bateaux taïwanais ont capturé accessoirement le thon obèse entre le début des années soixante et la fin des années quatre-vingt. Entre 1968 et 1975, ces prises était élevées, puis ont diminué par la suite et le thon obèse est devenu une espèce cible à partir de 1990. Les déclarations historiques de capture ont été actualisées pour les années 1991, 1992 et 1994.

La standardisation des indices d'abondance a été effectuée à l'aide du Modèle Linéaire Généralisé (GLM) pour les données provenant des carnets de pêche taïwanais. Trois effets simples (année, mois et sous-zone de pêche) ont été utilisés dans le modèle GLM pour les périodes 1968-1976, 1975-1988, 1988-1994 et 1968-1994. Les résultats indiquent que les valeurs résiduelles obtenues à partir de l'ajustement du modèle étaient négatives à la validation dans l'hypothèse normale de l'erreur mais qu'elles étaient relativement semblables en ce qui concerne la tendance de la CPUE pour les quatre périodes. La CPUE standardisée de 1968-1994 a donc été sélectionnée pour la pêcherie palangrière taïwanaise dans l'Atlantique entier. Les séries de CPUE standardisées indiquent une légère fluctuation avec une tendance à la baisse entre le début de la pêcherie et 1989 (chiffre minimal), puis une augmentation accompagnée de fluctuations depuis cette date.

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RESUMEN

Taiwan se ha convertido en una de las naciones que captura patudo con palangre en el Atlántico desde 1990; cambió su especie objetivo de atún blanco a túnidos tropicales, y, a continuación de los japoneses, Taiwan introdujo recientemente el palangre profundo en el Atlántico tropical. Con el fin de abarcar y regular la pesquería, el informe actual trata de verificar los datos de captura histórica y trata de utilizar datos aplicables de cuadernos de pesca para estandarizar las tasas de abundancia como índices de abundancia.

Los datos de las capturas históricas revelan que los taiwaneses capturan patudo como captura fortuita desde comienzos de 1960 hasta finales de 1980, período en el cual tuvo lugar una fuerte captura, entre 1968 a 1975, y decreció de forma significativa a partir de entonces. Los registros históricos de captura se actualizaron para 1991, 1992 y 1994.

La estandarización de los índices de abundancia se efectuó utilizando un modelo lineal generalizado (GLM) para datos agregados de cuadernos de pesca de Taiwan. Tres efectos singulares, año, mes y subzona pesquera se utilizaron en el modelo GLM para los períodos temporales 1968-1976, 1975-1988, 1988-1994 y 1968-1994. Los resultados muestran que los residuos obtenidos del ajuste GLM eran menos válidos para el supuesto normal de error, pero durante cuatro períodos no se observó una tendencia distinta en la captura relativa por unidad de esfuerzo (CPUE). En consecuencia, se seleccionó la CPUE estandarizada de 1968-1994 para la pesquería de palangre de Taiwan en el Atlántico total. La serie estandarizada de CPUE muestra una tendencia ligeramente al descenso desde el comienzo de la pesquería de Taiwan al punto más bajo en 1989, después se incrementó y fluctuó a partir de entonces.

INTRODUCTION

Atlantic bigeye tuna (*Thunnus obseus*) has become one of most important target species for Taiwanese longline fishery since 1990. The stock has been exploited by three major gears, and Taiwanese, shared with Japanese and Korean, use longline gear to fish bigeye tuna around tropical Atlantic.

A large part of bigeye tuna catch by Taiwanese are made by longline vessels with super-cold freezer operating deeper than conventional longline fleets deployed. Liu and Hsu (1991) and Chang and Hsu (1993) report the comparison of conventional and deep longline gear configuration. Taiwanese longline fleets operating deeper for cold-water species incepted during the mid-1970's, and mainly operated in the Indian Ocean to target bigeye tuna and yellowfin tuna. Further, the deep longline vessels grow significantly from 1986, there were about 300 vessels in the early 1990's. and about 335 vessels in 1995. Moreover, part of those vessels introduced to Atlantic to target bigeye tuna and yellowfin tuna may start in 1987, and significantly operated in Atlantic from 1990. And about 67 vessels in 1995 and 112 vessels in 1996 operated in the Atlantic (personal communication, H. F. Fu, Secretary of Taiwan Tuna Fishing Boats and Fishery Export Association). However there are no apparent item available in the logbooks for distinguishing both operations till 1994.

Since then, Taiwanese longline fishery started in the Atlantic, Taiwan haven't change by-catch status for incidently fishing the bigeye tuna. However, target status likely started either perhaps from 1990 or possibly from 1988, because a number of longline fleets with super-cold freezer introduced into Atlantic from that time. As the result, research of the stock is planned for attempting to collect those fishery data, to verify them and to estimate abundance indices for Taiwanese longline fishery from 1995. This paper aims at the purposes for verifying historical catch data and standardizing catch per unit effort as abundance indices.

MATERIAL AND METHOD

1. Data used

Landing data of Taiwanese longline fishery in the Atlantic are provided by the Council of Agriculture, Taiwan. The historical landings were given in Table 1 with comparison to Task I bases of International Commission for the Conservation of Atlantic Tunas. A significant difference appeared in the years of 1991, 1992 and 1994 in which a number of new landing data have been obtained to improve and update those previous reported catches (Chang and Ho 1996) during 1996 Albacore Session (August 5 - 9, 1996, Taipei, Taiwan).

While the 1991, 1992 and 1994 landings were updated, the Task II monthly 5x5 square data have also been updated by increasing logbook coverage rate (Chang and Ho 1996). The catches and fishing effort of these new Task II data were used in standardizing catch per unit effort.

2. GLM standardization for catch per unit effort

One stock hypothesis for bigeye tuna in the total Atlantic was assumed to standardize catch per unit effort.

Due to unavailability of hooks per basket information, the gear configuration factor was not used in the present study. And possibly to eliminate the effect of target, a considerable stratification of fishing area was done in according to the investigation of distributions of catch per unit effort and fishing effort for Taiwanese longline fishery by aggregated data of 5x5 square area (Task II) from 1968 to 1994. Consequently, seven sub-areas were made as given in Fig. 1. However, sub-area 3 (Fig. 1) was not used because of too many missing data.

Standardized catch rates (catch per unit effort, CPUE) for total Atlantic from Taiwanese longline fishery were made by three time segments, 1968-1976, 1975-1988, and 1988-1994, and complete time series, 1968-1994 in which the Task II data were available. Thus, standardized annual abundance was estimated by general linear model (GLM) with the assumption of normal error structure. Zero catch observations were included in the model with an addition of 0.001 in the dependent term in order to prevent the undefined logarithmic transformation and to obtain possibly better normal residuals (Uojumi 1996). Also the fishing effort less than 5000 hooks for each square area was excluded. Therefore, the GLM model was selected as:

$$\mathrm{LOG}(\mathrm{CPUE}+0.001)=\mu+Y+M+A+\varepsilon$$

where μ = overall mean; Y = yearly effect; M = monthly effect; A = fishing sub-area effect, and; ε = error term assumed as normal distribution with zero mean and σ^2.

The nominal monthly 5x5 square area catch per unit effort in number were logarithmically transformed and were used as dependent variable in GLM model. The two way interaction of quarter and sub-area was not used in analysis because the interaction has caused that the yearly abundance indices cannot be estimated by the GLM model during the pretest. Therefore, we excluded all interactions during the analysis, and the GLM model was adopted as above shown. The standardized CPUEs are in number per 1000 hooks, and standardized CPUEs in weight were obtained by standardized CPUEs in number per 1000 hooks multiplying the corresponding mean weight each year. Finally, the standardized CPUEs in weight were scaled by their overall mean.

RESULTS

I. Landings

The updated catches are given in Table 1. The abrupt change of landings has occurred since 1991 (Fig. 2). The 1991 and 1992 catches increased, and 1994 catch decreased in comparison with the previous reports. Those changes of bigeye tuna catches by Taiwanese longline fishery are mainly improved by new returns of logbook and chandlers' report information (Chang and Ho 1996; Chang and Chern 1996).

II. Standardized abundance indices

The stratification of sub-area was according to the distribution of catch per unit effort and fishing effort based on monthly 5x5 square area of Taiwanese longline fishery for bigeye tuna in the Atlantic from 1968 to 1994. The ICCAT length sampling area for bigeye tuna was also referred. The sub-area used in GLM analysis was mapped in Fig. 1.

Under the assumption of log-normal random error, the ANOVA analysis obtained from GLM fitting the nominal catch rates of bigeye tuna by Taiwanese longline fishery in four periods 1968-1976, 1975-1988, 1988-1994 and 1968-1994 were done as shown in Table 2. During fittings, two way interaction made the estimates of yearly abundance indices unavailable, thus the two way interaction of quarter-sub-area was excluded in the analysis. And the year, quarter and sub-area effects show significant factors in the GLM analysis.

Those analyses show that the present fittings of GLM model for the four time series data seem not much satisfied (Table 2 and Fig. 3). R^2s indicate that the GLM model with normal error assumption explains a few percentages of variability incorporating with year, month and sub-area factors. The residual plots (Fig. 3) for those fittings show that the assumption is on less validation.

However, Table 3 tabulates the scaled standardized catch per unit effort (in weight before scaling) of bigeye tuna for those four time series. Fig. 4 shows the relative standardized abundance indices. To look at the similar tendency of those relative abundance indices, the results point out that the 1968-1994 series can represent the Atlantic bigeye tuna abundance for Taiwanese longline fishery (Fig. 4). Therefore, the 1968-1994 standardized catch per unit effort of bigeye tuna for Taiwanese longline fishery in the Atlantic, incorporating its 90% confidence interval is shown in Fig. 5.

DISCUSSION

Atlantic bigeye tuna information for Taiwanese longline fishery was updated. Bigeye tuna caught by Taiwanese longline fleets in the Atlantic were in by-catch status before sometimes in late 1980's. In accompany with increasing longline vessels with super-cold freezer, bigeye tuna was shifted to become as one of targeted tunas in the Indian and Atlantic for these fleets. In the Atlantic, total annual bigeye tuna catch increased to over 10,000 MT from 1991 (Table 1).

The results of standardized catch per unit effort as abundance indices for total Atlantic reveal that: (1) the sub-area occupies most abundance variation, (2) monthly effect as well as quarterly effect is significant, (3) the standardized CPUEs using different time periods show similar trend, (4) the results of residual analysis point out the question of validation of normal error assumption, the standardization should be redone in future under either using alternative error assumption or verifying the data bases, and (5) the standardized CPUE of bigeye tuna tends to fluctuated decreasing from the beginning of Taiwanese longline fishery operating in the Atlantic, and drops to the lowest level in 1989, then increased slightly onward.

Concerning the great variability for sub-area effect, there are two main possible reasons: one is the inappropriate stratification of fishing region, and other is not verifying logbook data information that may include disturbance inside the data. The later should be verified by means of set by set data, and the former should stratify fishing sub-area as small as possible. These works should be redone in future. And AIC criterion (Akaike's Information Criterion, Uojumi 1996) may be used in determining appropriate factors and interactions incorporating with GLM analysis.

The similar trend found in standardized CPUEs for different time segments may indicate that the standardized CPUEs seems reliable, and that the temporal stratification for different time periods is not necessary when catch rates of Taiwanese longline fishery for bigeye tuna was standardized. Therefore, a long time period of 1968-1994 in which the Task II data were available is used to obtain the representative of abundance indices of Atlantic bigeye tuna for Taiwanese longline fishery.

Summarized the results, the tendency of standardized 1968-1994 catch per unit effort seems coincident with the changes of Taiwanese longline fishery in the Atlantic. Based on the development history of Taiwanese longline fishery , the fishery operates in tropical area and fishes mainly bigeye tuna and yellowfin tuna from early 1960's to middle 1970's; then the fishery expands fishing grounds and changes target, the catches of bigeye tuna and yellowfin tuna relatively decreased from middle 1970's to late 1980's; and recently, the fishery changes fishing pattern and facility of freezer in order to promote quality of tunas, bigeye tuna and yellowfin tuna again become targeting as well as albacore. However, it seems superficially that Taiwanese longline fishery targets different species during different time periods, we would rather conclude that the catches of bigeye tuna and yellowfin tuna by Taiwanese longline fishery in the Atlantic may depend upon in which the longline vessels operate. As this premise is true, the standardized 1968-1994 CPUE series of bigeye tuna in this report may represent the abundance indices of Taiwanese longline fishery. We recommend that the study be continued deeply in future.

ACKNOWLEDGEMENTS

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Table 1 The landings (metric tones, MT) provided by the Council of Agriculture, Taiwan, and the Task I bases of International Commission for the Conservation of Atlantic Tunas from 1965 to 1995.

Year	Landings	Task I
1965	0	0
1966	595	595
1967	2231	2231
1968	5344	5344
1969	7483	7483
1970	7555	7555
1971	5479	5479
1972	4990	4990
1973	3818	3818
1974	3097	3097
1975	3950	3950
1976	3274	3274
1977	2978	2978
1978	2628	2628
1979	2200	2200
1980	2266	2266
1981	1670	1670
1982	1900	1900
1983	1436	1436
1984	818	818
1985	1079	1079
1986	995	995
1987	1317	1317
1988	1300	1300
1989	717	717
1990	4899	4899
1991	12083	766
1992	10218	4749
1993	11881	11881
1994	17416	19479
1995	15950	

Table 2 The ANOVA test for the effects of GLM model

(1) fitted from 1968 to 1976.

Source	DF	Sum of squares	Mean square	F value	Pr>F
Model	24	4875.0513	203.1271	43.09	0.0001
Year	8	760.4598	95.7505	20.16	0.0001
Month	11	721.7806	65.6164	13.92	0.0001
Area	5	2442.9666	488.5933	103.64	0.0001
Error	3346	15774.3332	4.7144		
Corrected total	3370	20649.3845			

R-square	C.V.	Root MSE	Log(mean)
0.2361	-643.683	2.1713	-0.3421

(2) fitted from 1975 to 1988

Source	DF	Sum of square	Mean square	F value	Pr>F
Model	30	6598.9207	219.940	38.69	0.0001
Year	14	1911.5297	136.5378	24.02	0.0001
Month	11	632.4546	57.4959	10.11	0.0001
Area	5	3945.0764	789.0153	138.78	0.0001
Error	5589	31776.2049			
Corrected total	5619	38375.1256			

R-square	C.V.	Root MSE	Log(mean)
0.1720	-142.866	2.3844	-1.6690

(3) fitted from 1988 to 1994

Source	DF	Sum of square	Mean square	F value	Pr>F
Model	22	685.4104	294.7914	37.78	0.0001
Year	6	662.7058	110.4510	14.15	0.0001
Month	11	599.2054	54.4732	6.98	0.0001
Area	5	4695.6647	939.1329	120.35	0.0001
Error	2297	17924.5553			
Corrected total	2319	24409.9657			

R-square	C.V.	Root MSE	Log(mean)
0.2659	-208.4666	2.7935	-1.3400

(4) fitted from 1968 to 1994

Source	DF	Sum of square	Mean square	F value	Pr>F
Model	42	17457.7789	415.6614	70.54	0.0001
Year	26	434.3483	167.4749	28.42	0.0001
Month	11	1185.3301	107.7573	18.29	0.0001
Area	5	8651.8935	1730.3787	293.64	0.0001
Error	10244	60366.0109	5.8928		
Corrected total	10286	77823.7898			

R-square	C.V.	Root MSE	Log(mean)
0.2243	-211.727	2.4275	-1.14653

Table 3 Relative standardized catch per unit effort of bigeye tuna for Taiwanese longline fishery in the Atlantic from 1968 to 1994

Year	Nominal effort (1000 hooks)	Relative CPUE (1)	Relative CPUE (2)	Relative CPUE (3)	Relative CPUE (4)
1968	1,839	1.8489			2.9950
1969	28,303	2.0132			3.4920
1970	36,281	1.6331			3.0641
1971	35,361	1.0855			1.8683
1972	51,497	0.6670			1.3030
1973	49,199	0.4682			0.9607
1974	54,275	0.5115			1.0788
1975	49,335	0.4111	1.5883		0.8810
1976	45,410	0.3616	1.4244		0.7734
1977	55,015		2.0245		1.0619
1978	71,170		1.4676		0.8005
1979	58,003		1.0320		0.5368
1980	42,022		2.1776		1.1551
1981	43,472		1.7365		0.9643
1982	52,432		0.9768		0.5301
1983	67,498		0.9285		0.4930
1984	48,412		0.8451		0.4529
1985	49,516		0.7078		0.3783
1986	86,017		0.3284		0.1851
1987	128,322		0.7056		0.3945
1988	110,336		0.2733	0.4198	0.1543
1989	77,970		0.2481	0.3039	0.1333
1990	89,424			2.0167	0.8330
1991	108,927			0.7854	0.4766
1992	134,247			1.0952	0.7577
1993	124,577			0.7396	0.4536
1994	123,480			1.6395	0.8225
1995	107,771				

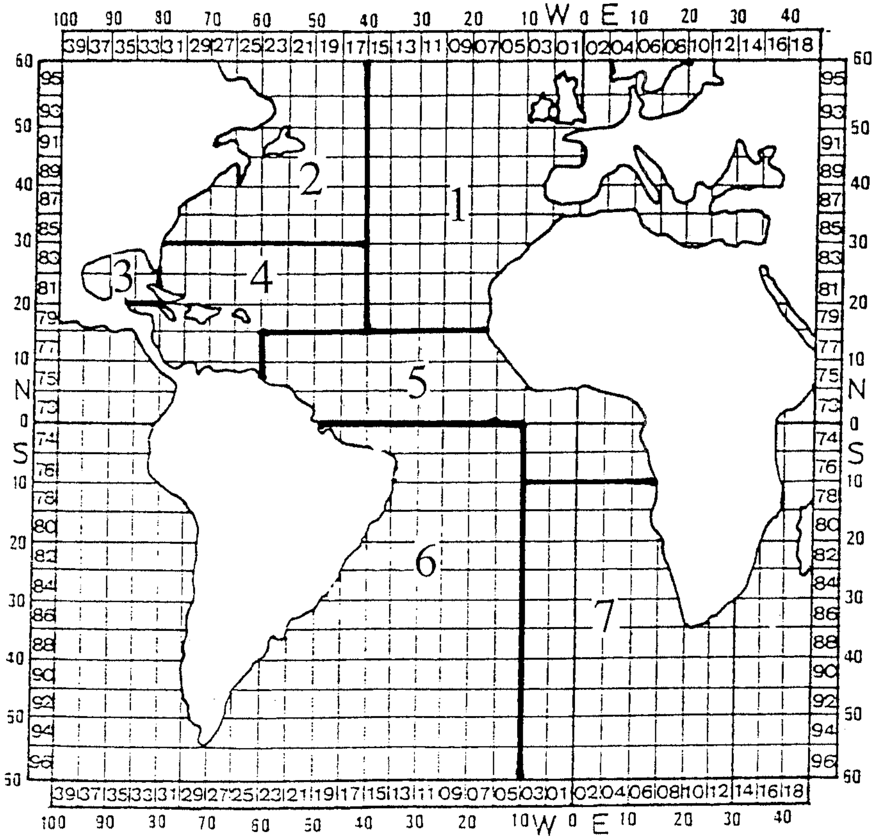


Fig. 1 Map of sub-areas stratified in according to the distribution of catch per unit effort and fishing effort of Taiwanese longline fishery for bigeye tuna in the Atlantic, the sub-areas are used to standardize abundance indices by GLM method. The 5x5-degree grids indicate the fundamental basis of catch statistics for Taiwanese longline fishery.

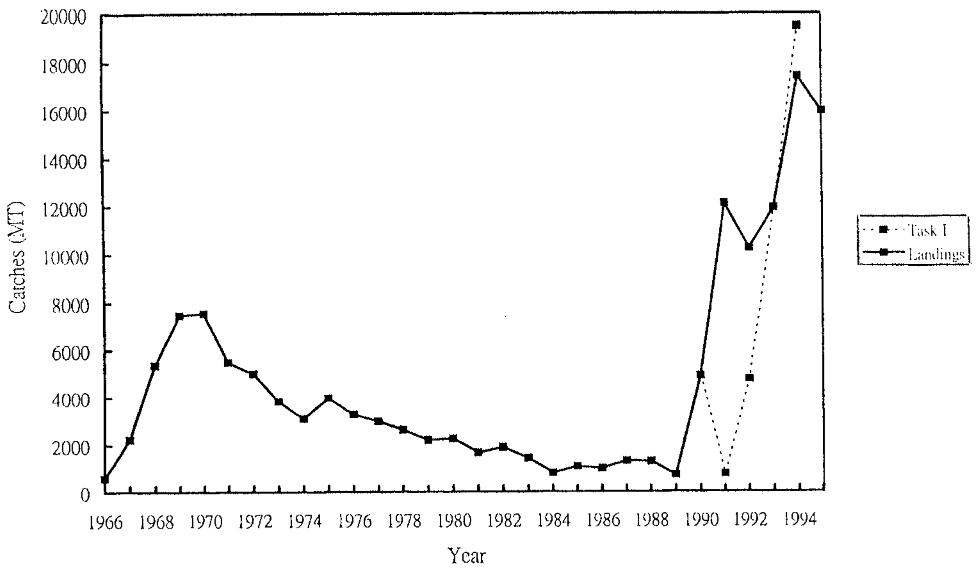
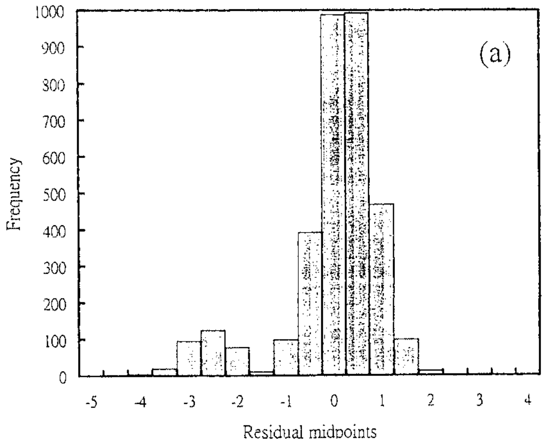


Fig. 2 Historical changes of landings (Task 1) of bigeye tuna by Taiwanese longline fishery in the Atlantic, the data of "Task I" are previously reported by Taiwan national scientists, and "landings" are reported by Oversea Fishery Development Council, the significant differences appear in 1991, 1992 and 1994.



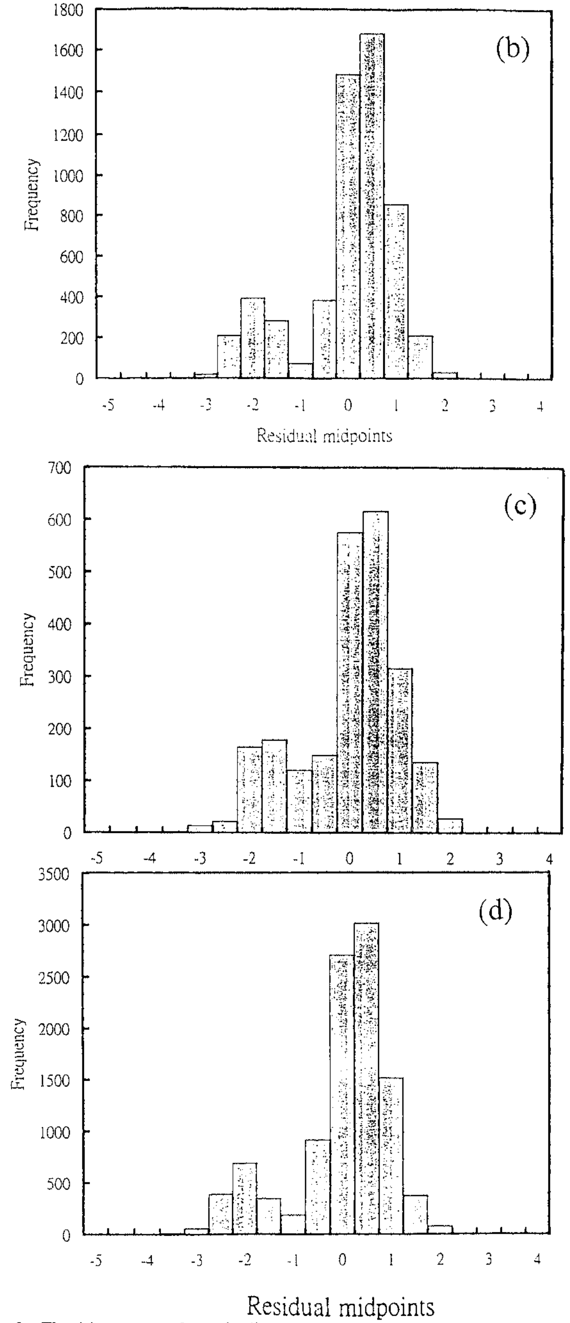


Fig. 3 The histogram of standardized residuals from fitting GLM for showing the normality of standardizing Taiwanese longline fishery for bigeye tuna in the Atlantic, panels (a) indicate 1968-1976 series; (b) 1975-1988 series; (c) 1988-1994 series, and (d) 1968-1994 series, all series seem to show invalid normal error assumption.

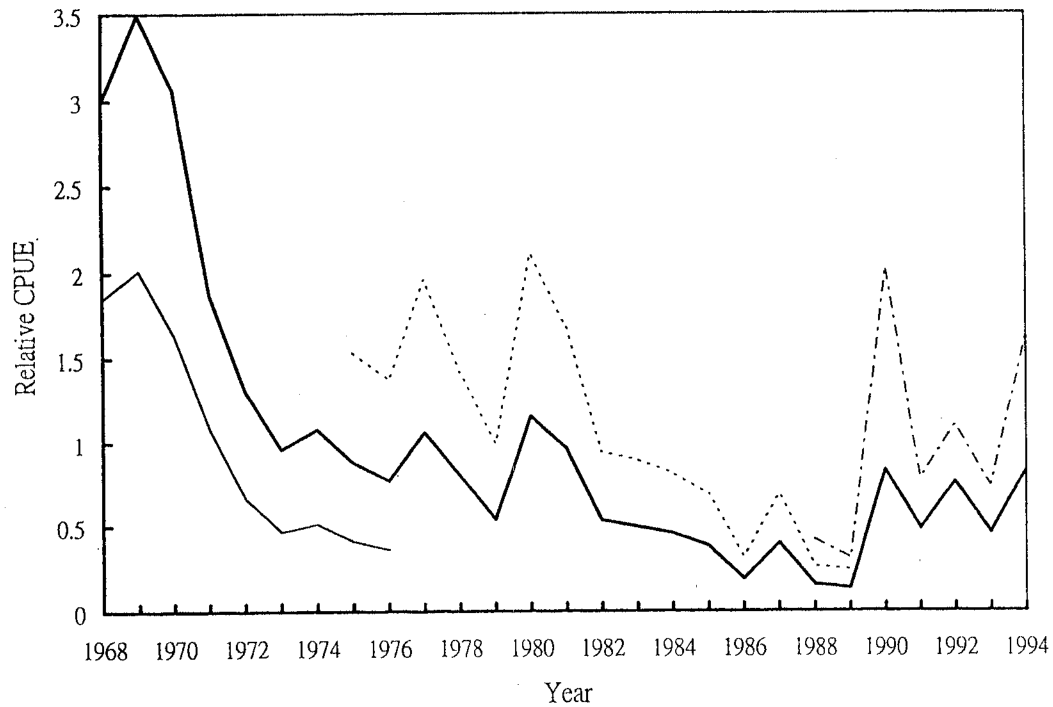


Fig. 4 The relative standardized catch per unit effort of bigeye tuna for Taiwanese longline fishery by means of 1968-1976 (thin solid curve), 1975-1988 (dash curve), 1988-1994 (dash-dot curve)and 1968-1994 (thick solid curve) time series, those curves indicate very similar trends.

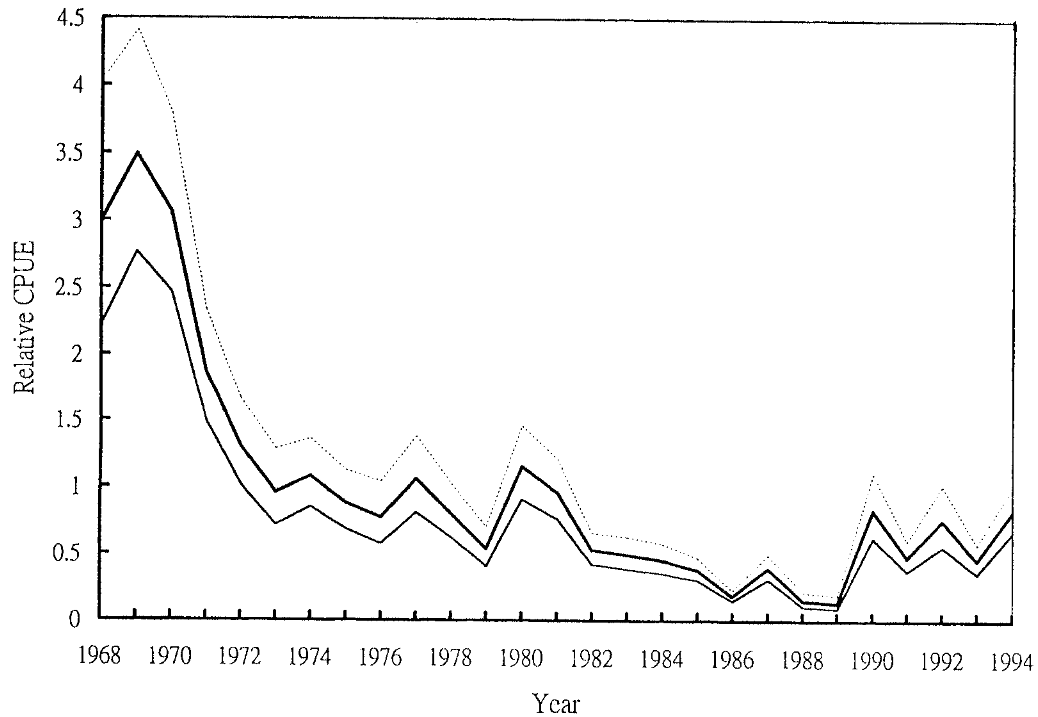


Fig. 5 The relative standardized catch per unit effort of bigeye tuna for Taiwanese longline fishery by means of 1968-1994 series, 95% confidence interval is also shown in the same figure.