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STANDARDIZATION OF CPUE FOR YELLOWFIN TUNA CAUGHT BY TAIWANESE LONGLINE FISHERY IN THE ATLANTIC

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SUMMARY

The CPUE of the Taiwanese longline fishery for Atlantic yellowfin tuna from 1968 to 1994 was standardized by Generalized Linear Model(GLM) with log-normal error structure in the Atlantic. The effects of year, fishing season, and area were incorporated in the model. The standardization was carried out under the single stock hypothesis in the Atlantic. The standardized CPUE decreased rapidly in the late 1960s, and continued to decrease gradually until 1978, and then increased slightly and has fluctuated since then.

RÉSUMÉ

La CPUE de la pêcherie palangrière taïwanaise d'albacore dans l'Atlantique entre 1968 et 1994 a été standardisée avec le Modèle Linéaire Généralisé et une structure log-normale de l'erreur. Les effets année, saison de pêche et zone ont été pris en compte dans le modèle. La standardisation a été effectuée dans l'hypothèse d'un stock unique de l'Atlantique. La CPUE standardisée indique une diminution rapide à la fin des années soixante, suivie d'une diminution progressive jusqu'en 1978 puis d'une légère augmentation accompagnée de fluctuations à partir de cette date.

RESUMEN

La CPUE de la pesquería de palangre taiwanesa para rabil del Atlántico y el período 1986-1994, se normalizó mediante técnicas del Modelo Lineal Generalizado (GLM) con estructura de error logarítmico normal en el Atlántico. Al modelo se incorporaron los efectos de año, temporada de pesca y zona. La normalización se hizo bajo la hipótesis de un sólo stock en el Atlántico. La CPUE normalizada descendió con rapidez a finales de los años 60 y siguió en descenso gradual hasta 1978, aumentando a continuación ligeramente, con fluctuaciones.

Introduction

The yellowfin tuna, *Thunnus albacares*, is a pantropical species, and i.e. one of the important target for Taiwanese longline fishery in the Atlantic. Taiwanese longline fishery operates in a wide area, continuous throughout the entire Atlantic and fishes yellowfin tuna in the tropical region between 15°N and 10°S. The historical yellowfin tuna catch by Taiwanese longline fishery is given in Table 1 and Fig. 1. The low catch from middle 1970s to late 1980s may be due to the change of the fishing effort distribution and target species.

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Up to 1990, the Atlantic yellowfin assessments were done using the hypothesis of two independent stocks in the eastern and western Atlantic. This hypothesis is contradicted by some of the information currently available on the stock structure(Anon. 1994). Consequently, the ICCAT Working Group developed the hypothesis of one stock of Atlantic yellowfin tuna, with a principle, well-defined spawning area in the East Atlantic in the Equatorial area, a migration of pre-adults from the eastern Atlantic towards the west, and a spawning migration of adults from the west towards the equatorial spawing area in the eastern Atlantic. Followed those, a hypothetical migration model for a single Atlantic stock of yellowfin tuna is developed (Anon. 1994), and the model is given in Fig. 2. In this report, all of the procedures were pursued on the basis of the single migratory stock hypothesis.

The nominal CPUE was effected by many factors such as operational, biological, and environmental ones. The standardization becomes essential before we use them. General linear model (GLM) has been used in the standardization with the assumption that the error structure belongs to log-normal distribution (Nakano et al., 1992). The present report aims to use the GLM to obtain the standardize CPUE trend of yellowfin tuna for 1968 to 1994.

Materials and Methods

1. Basic data

The basic data were obtained from the Taiwanese longline fishery statistics compiled at the Institute Oceanography, National Taiwan University for 1968-1994, the data of 1991, 1992 and 1994 were updated by Oversea Fisheries Development Council. The data base contains monthly 5 x 5 square block catch and effort for the year 1968-1994.

2. Nominal catch per unit effort

Nominal catch per unit effort (nominal CPUE) was calculated by catch in number divided by effort (per 1000 hooks) for monthly 5 by 5 square block. Therefore, catch per unit effort in number was used in standardization.

3. The GLM model

General linear model was used to standardize CPUE of yellowfin tuna with the main effects of year, fishing season, and fishing area. Calendar quarter was used for fishing season. Roughly looking, fishing area by Taiwanese longline fishery for yellowfin tuna can be divided into two areas, i.e. major fishing area: between 15°N and 10°S ; secondary fishing area: elsewhere. Table 2 indicates the number of data points of the two areas.

In order to layout the similar catch per unit effort and fishing effort employed at fishing area as possible, a temporal stratification of 1968-1972, 1973-1989 and 1990-1994, was made for the change of fishing pattern, by means of CPUE and effort distributions (Figs. 3~8). Consequently, 7 subareas were selected (Fig. 9) for the first two periods (1968-72 and 1973-89), and 7 subareas (Fig. 9) for the third period (1990-94). The gear configuration was not used in the present analysis, because number of hooks per basket information is not available.

The multiplicative GLM model with log-normal distribution is as followed:

$$\log(CPUE+0.001)= \mu + Y + Q + A + \text{interactions} + \varepsilon$$

where

μ = overall mean;

Y = yearly effect;

Q = quarterly effect;

A = fishing subarea effect; and

ε = error term assumed as normal distribution with zero mean and σ^2

The constant, 0.001 , was chosen for preenting illegal transformation of zero catch in which Uojumi (1996) used in the 3rd ICCAT Billfishes Workshop, also the constant can result in a good normalized assumption was met in its model. The model with all of the combinations of two-way interactions was attempted to fit except for the interactions which had lack of observations.

Model selection was made using Akaike's Information Criterion (AIC) (Uosaki, 1996):

$$AIC = X\log(MSE) + 2Y$$

where X is number of observation, MSE is mean square error, and Y is number of parameters.

Analysis included 1968-1972, 1973-1989, and 1990-1994 time series TASK II data of Taiwanese longline figheries for the Atlantic, and the computation was made through computer software SAS ver. 6.08.

Results and Discussion

The obtained AICs for GLM models are listed in Table 2 for the three periods. The final model chosen for each period is :

1968-1972: log(CPUE+0.001)= μ + Y + Q + A + Q*A
1973-1989: log(CPUE+0.001)= μ + Y + Q + A + Q*A
1990-1994: log(CPUE+0.001)= μ + Y + Q + A + Y*A

The ANOVA tables for the final models was shown in Tables 4~6. F values of the effect of subarea were the largest among the effects. Those factors in the GLM model explain 0.531, 0.302 and 0.295 total variations for the three time series data, resepectively. There are many other factors which are not included in the standardization and the low value of R-square suggests these other factors may affect validation of model application.

Fig. 10 showed the standardized residuals of the GLM model for each period. The distributions of the standardized residuals were not far from normal distribution in periods 1968-72 and 1990-94, though the distribution of standardized residuals skewed to the positive side. In the second period (1973-89), the distribution of standardized residuals is likely to have two modes, a change of fishing effort distribution (east toward west) may cause this irregularity.

The nominal-CPUE and standard-CPUE for the stock are given in Table 7. The standard-CPUEs with lower and upper 95% confidence limit are given in Fig. 11. The standardized CPUE decreased rapidly in the end of 1960's, continued to decrease gradually up to 1978, and then slightly increased with fluctuations. The distribution of nominal-CPUE almost match the single migratory stock hypothesis.

The distribution pattern of fishing effort changed significanly both in the middle 1970's and late 1980s due to the change of the target species. As the result, number of observations also changed. (Table 2). There is significant difference in the distribution pattern between CPUE and fishing effort. Therefore, there was no sufficient observations on the main distribution area of yellowfin tuna, especially for the second period (1973-89), this discrepancy may introduce bias on the CPUE estimates.

References

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Table 1 The total catch of yellowfin tuna by Taiwanese longline fishery from 1968 to 1994.

Year	Total catch (MT)
1968	7862
1969	10798
1970	7071
1971	4370
1972	4705
1973	2655
1974	2327
1975	2362
1976	1736
1977	329
1978	340
1979	918
1980	608
1981	767
1982	540
1983	477
1984	572
1985	768
1986	1248
1987	763
1988	1383
1989	599
1990	3014
1991	3692
1992	4007
1993	3713
1994	6714

Table 2 Number of observations by year for major (15°N～10°S) and secondary (elsewhere) fishing area.

Year	Major fishing area	Secondary fishing area	Total Atlantic
1968	137	131	268
1969	171	281	452
1970	220	406	626
1971	190	282	472
1972	94	294	388
1973	33	234	267
1974	56	384	440
1975	60	320	380
1976	16	248	264
1977	23	344	367
1978	16	392	408
1979	6	333	339
1980	27	433	460
1981	54	437	491
1982	48	506	554
1983	24	413	437
1984	30	389	419
1985	28	489	517
1986	18	569	587
1987	18	439	457
1988	8	197	205
1989	14	191	205
1990	118	184	302
1991	149	284	433
1992	114	148	262
1993	129	295	424
1994	166	373	539

Table 3 Estimates of AIC for each GLM model. The value of AIC with under line shows the best model in each period.

1968-1972 Obs.=2172

Model	# Para.	R-square	C.V.	MSE	F	AIC
YQA	16	0.488	-190.453	6.7614	158.46	4183.1915
YQ	36	0.495	-189.773	6.7132	84.09	4207.6525
QA	44	0.531	-183.153	6.2529	78.1	<u>4069.3745</u>
YA	51	0.501	-189.137	6.6682	57.92	4223.0441
YQ QA	64	0.537	-182.373	6.1999	57.49	4090.886
YQ YA	71	0.507	-188.605	6.6308	44.47	4250.8277
QA YA	79	0.545	-181.282	6.1259	46.17	4094.8058
YQ QA YA	99	0.551	-180.601	6.0799	38.61	4118.4345

1973-1989 Obs.=6446

Model	# Para.	R-square	C.V.	MSE	F	AIC
YQA	28	0.262	-77.283	6.5833	91.34	12203.72
YQ	96	0.278	-76.763	6.4949	33.56	12252.577
QA	56	0.301	-75.297	6.2492	64.34	<u>11923.995</u>
YQ QA	124	0.318	-74.699	6.1503	32.55	11957.165

1990-1994 Obs.=1948

Model	# Para.	R-square	C.V.	MSE	F	AIC
YQA	16	0.26	-139.785	7.4657	52.28	3948.1018
YQ	36	0.265	-139.727	7.4595	27.75	3986.4834
QA	44	0.277	-138.81	7.3619	23.69	3976.8276
YA	51	0.295	-137.261	7.1985	21.64	<u>3947.104</u>
YQ QA	64	0.281	-138.857	7.3669	17.32	4018.1501
YQ YA	71	0.301	-137.127	7.1844	16.69	3983.2846
QA YA	79	0.313	-136.188	7.0865	15.66	3972.5572
YQ QA YA	99	0.317	-136.256	7.0915	13.01	4013.9311

Table 4 ANOVA for Atlantic yellowfin tuna from 1968 to 1972

R-Square=0.531, Coefficient of Variation=-183.153

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	31	15138.333	488.3333	78.1	0.0001
Error	2140	13381.304	6.2529		
Corrected Total	2171	28519.638			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	4	560.31	140.08	22.4	0.0001
QRT	3	59.58	19.86	3.18	0.0232
AREA	6	9476.54	1579.42	252.59	0.0001
QRT*AREA	18	1209.70	67.21	10.75	0.0001

Table 5 ANOVA for Atlantic yellowfin tuna from 1973 to 1989

R-Square=0.302, Coefficient of Variation=-75.2967

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	43	17289.576	402.0832	64.34	0.0001
Error	6402	40007.68	6.2492		
Corrected Total	6445	57297.256			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	16	1071.254	66.95337	10.71	0.0001
QRT	3	517.59981	172.53327	27.61	0.0001
AREA	6	9053.7398	1508.95663	241.46	0.0001
QRT*AREA	18	2257.1186	125.39548	20.07	0.0001

Table 6 ANOVA for Atlantic yellowfin tuna from 1990 to 1994

R-Square=0.295, Coefficient of Variation=-137.261

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	37	5763.3283	155.76563	21.64	0.0001
Error	1910	13749.125	7.1985		
Corrected Total	1947	19512.454			

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	4	563.39225	140.84806	19.57	0.0001
QRT	3	204.53424	68.17808	9.47	0.0001
AREA	6	4006.4388	667.7398	92.76	0.0001
YEAR*AREA	24	689.54365	28.73099	3.99	0.0001

Table 7 The nominal catch per unit effort and standardized catch per unit effort for 1968 to 1994.

YEAR	Nominal CPUE	Standardized CPUE
1968	9.33403	0.93420
1969	6.22878	0.99552
1970	2.88465	0.49012
1971	3.55596	0.25119
1972	3.31843	0.33805
1973	1.83218	0.22460
1974	1.72003	0.09019
1975	0.99786	0.08433
1976	0.32774	0.05943
1977	0.16067	0.06314
1978	0.15835	0.07752
1979	0.36395	0.12597
1980	0.32432	0.18736
1981	0.31063	0.19394
1982	0.23122	0.15182
1983	0.21744	0.15473
1984	0.39617	0.15779
1985	0.30670	0.15052
1986	0.50361	0.21605
1987	0.50731	0.23090
1988	0.64681	0.15953
1989	0.41339	0.15452
1990	0.78623	0.03084
1991	1.10833	0.14379
1992	1.09969	0.11777
1993	1.02062	0.08565
1994	1.01180	0.23087

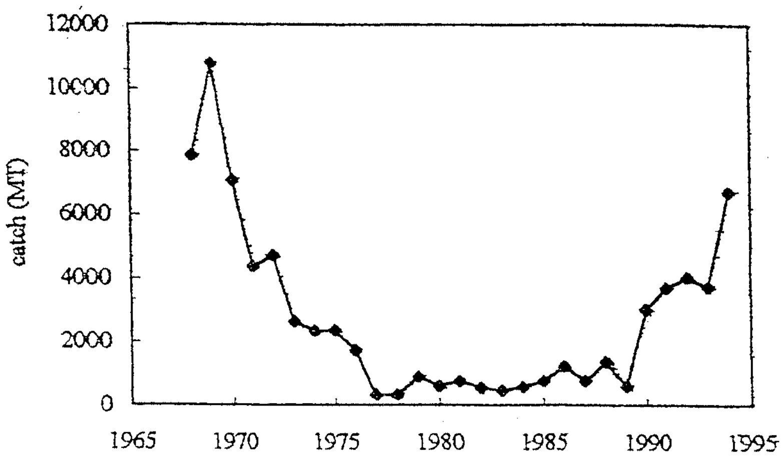

Fig 1 Nominal yellowfin tuna catch of the longline fisheries from 1968 to 1994.

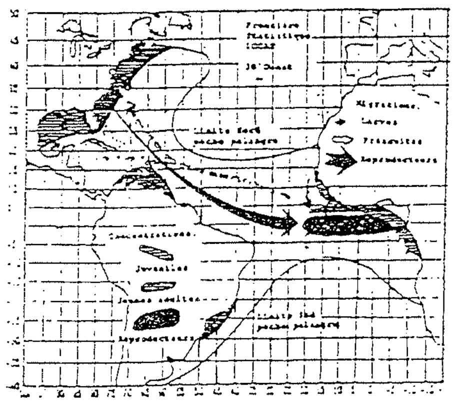

Fig. 2 Hypothetical migration model for a single Atlantic stock of yellowfin tuna.

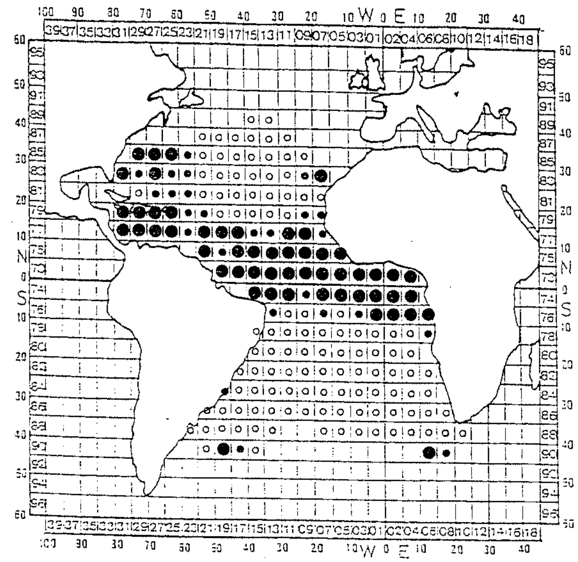

Fig.3 The nominal catch per unit effort (CPUE) distribution of averaging each annual 5x5 square block for yellowfin tuna by Taiwanese longline fishery in the Atlantic from 1968 to 1972, where open circle denotes CPUE is less than 2 individuals/1000 hooks, small solid circle denotes CPUE is between 2 individuals/1000 hooks and 5 individuals /1000 hooks, and large solid circle for greater than 5 individuals/1000 hooks.

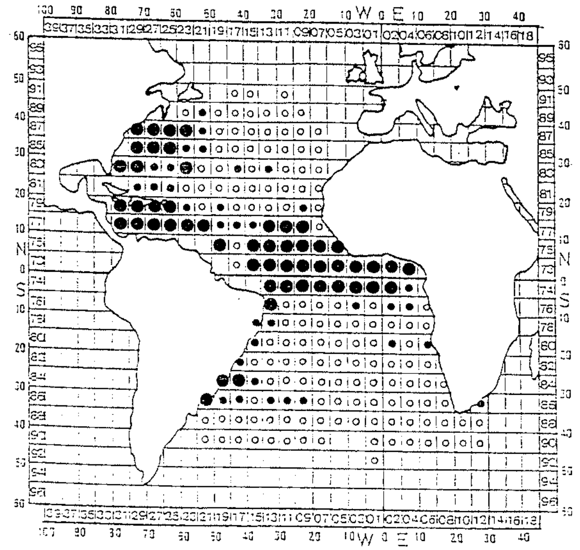

Fig.4 The nominal catch per unit effort (CPUE) distribution of averaging each annual 5x5 square block for yellowfin tuna by Taiwanese longline fishery in the Atlantic from 1973 to 1989, where open circle denotes CPUE is less than 0.5 individuals/1000 hooks, small solid circle denotes CPUE is between 0.5 individuals/1000 hooks and 1 individuals/1000 hooks, and large solid circle for greater than 1 individuals/1000 hooks.

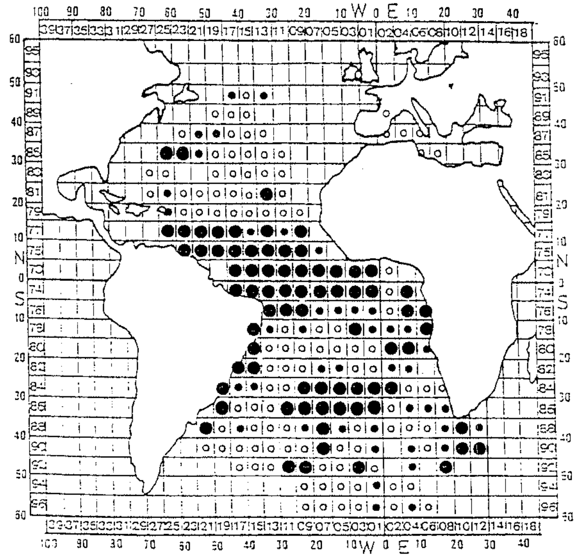

Fig.5 The nominal catch per unit effort (CPUE) distribution of averaging each annual 5x5 square block for yellowfin tuna by Taiwanese longline fishery in the Atlantic from 1990 to 1994, where open circle denotes CPUE is less than 0.5 individuals/1000 hooks, small solid circle denotes CPUE is between 0.5 individuals/1000 hooks and 1 individuals/1000 hooks, and large solid circle for greater than 1 individuals/1000 hooks.

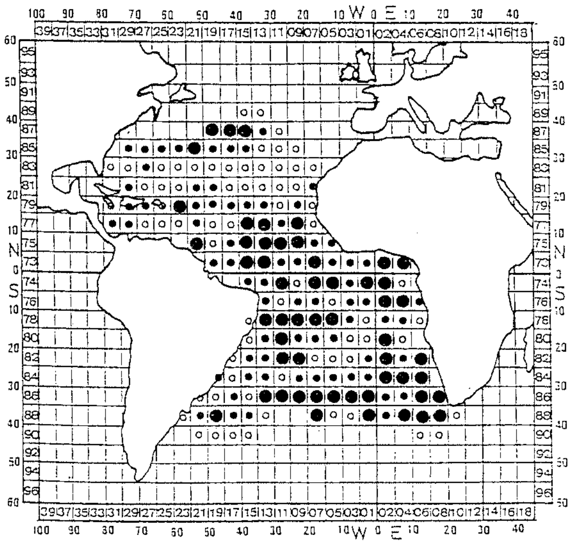

Fig.6 The nominal effort distribution of averaging each annual 5x5 square block for yellowfin tuna by Taiwanese longline fishery in the Atlantic from 1968 to 1972, where open circle denotes effort employed is less than 50,000 hooks, small solid circle denotes effort employed is between 50,000 hooks and 100,000 hooks, and large solid circle for greater than 100,000 hooks.

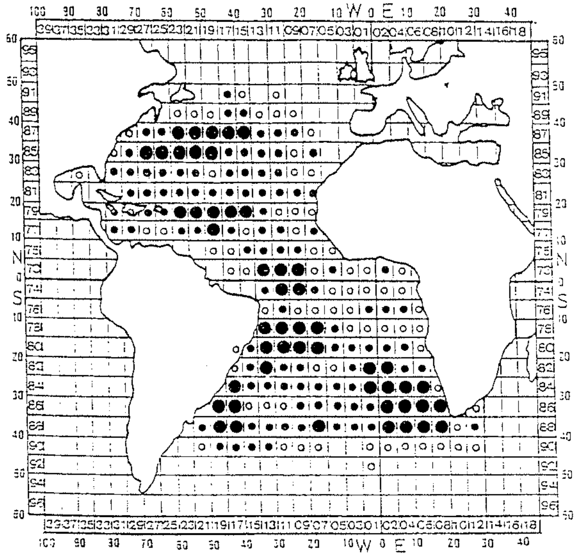

Fig.7 The nominal effort distribution of averaging each annual 5x5 square block for yellowfin tuna by Taiwanese longline fishery in the Atlantic from 1973 to 1989, where open circle denotes effort employed is less than 50,000 hooks, small solid circle denotes effort employed is between 50,000 hooks and 150,000 hooks, and large solid circle for greater than 150,000 hooks.

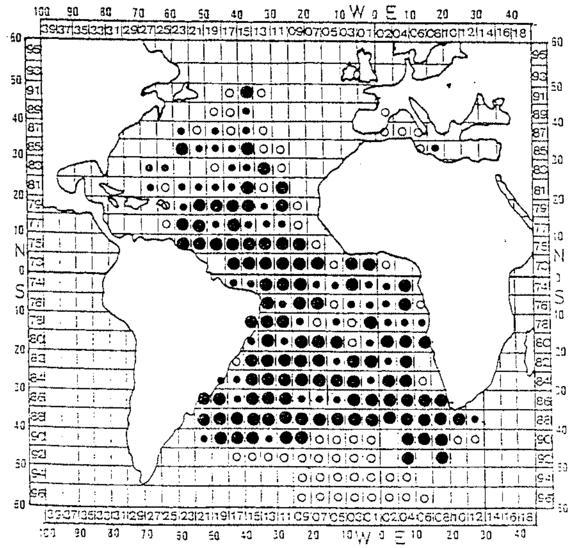

Fig. 8 The nominal effort distribution of averaging each annual 5x5 square block for yellowfin tuna by Taiwanese longline fishery in the Atlantic from 1990 to 1994, where open circle denotes effort employed is less than 100,000 hooks, small solid circle denotes effort employed is between 100,000 hooks and 200,000 hooks, and large solid circle for greater than 200,000 hooks.

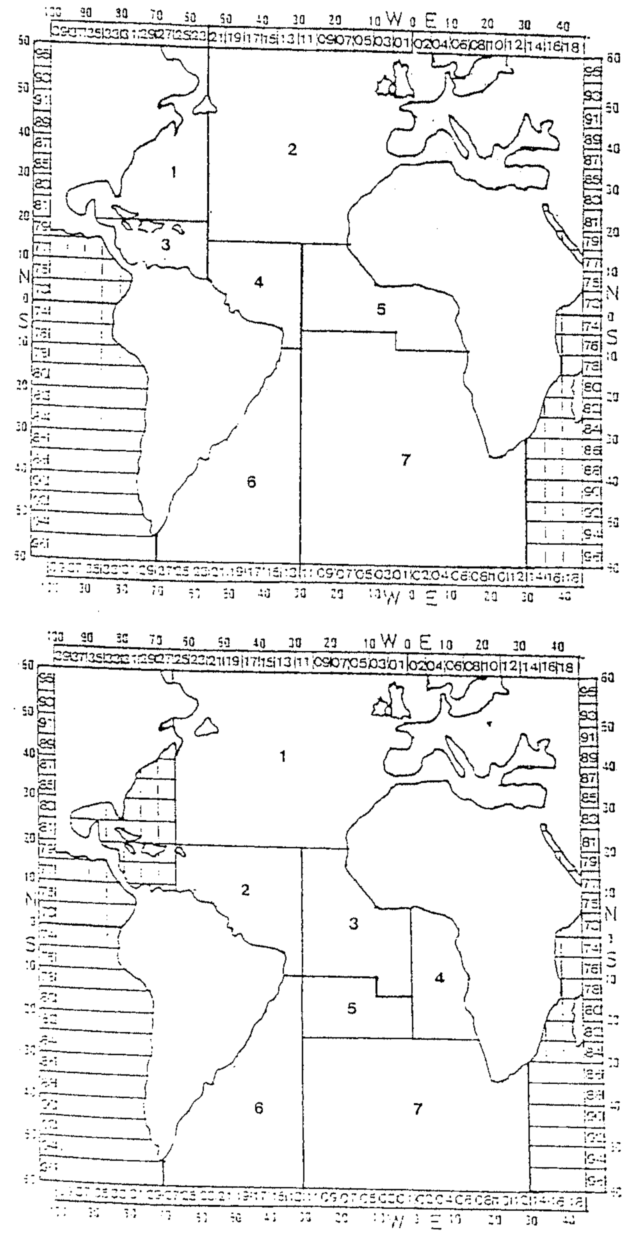

Fig. 9 Subarea used in the standardization of CPUE for yellowfin tuna Top: periods of 1968 to 1972 and 1973 to 1989, bottom: 1990 to 1994.

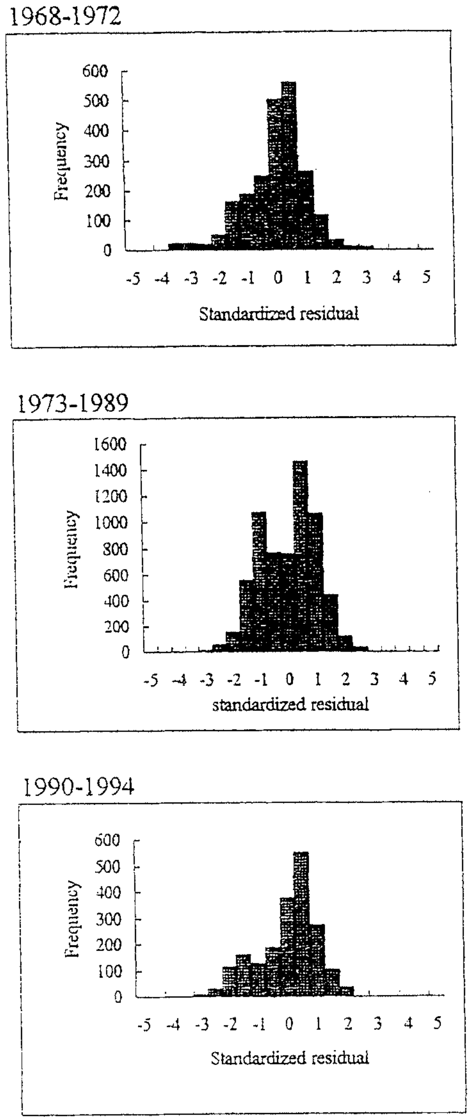

Fig. 10 The distribution of standardized residuals of GLM model in each period.

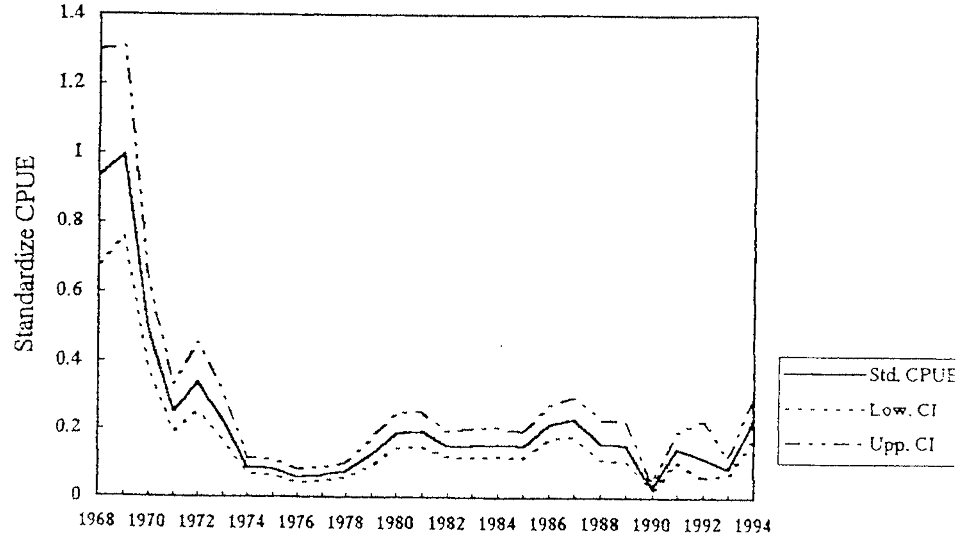

Fig. 11 Standardized CPUE of yellowfin tuna by GLM for Atlantic from 1968 to 1994. Dotted lines show upper and lower 95% confidance limits.