BIGEYE TUNA *(THUNNUS OBESUS)*, AGE-STRUCTURED PRODUCTION MODEL, CATCH PER UNIT EFFORT, GLM, GENMOD, MAXIMUM SUSTAINABLE YIELD, LONGLINE

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ABSTRACT

***One** bigeye tuna stock is assumed in the Indian Ocean, then Taiwanese, Japanese and Korean longline fishery data are used to derive the abundance indices which were standardized by general linear model (GLM) and generalized linear model (GENMOD or GM). Several factors were chosen to fit the models depending on the data availability of each fishery. Then, age structured production model (ASPM) analysis was used to assess the stock status of Indian bigeye tuna. Accordingly, the results of standardizing abundance indices show no significant difference among trends of standardized CPUE using the two models. The results obtained by ASPM analysis indicate that the maximum sustainable yield (MSY) is estimated about 116 thousand tons, which is slightly higher than the current catch in 1995. To evaluate the fishing mortality, spawning stock biomass, steepness and simulated abundance can elucidate that the Indian Ocean bigeye tuna stock is in full exploitation, and sustainability with high probability. However, the recent increase of fishing effort and continuously high catch has to be pre-cautious.*

INTRODUCTION

Taiwan is one of the leading nations using longline gear to fish tunas in the Indian Ocean. Of those tunas caught, bigeye tuna *(Thunnus obesus)* is one of the target species. In the Indian Ocean, Bigeye tuna occurs *45°S* northerly throughout the Indian Ocean. The major fishing ground is between 1 5"N and 1 *5°S* in the Indian Ocean for Taiwanese longline fishery. Catch of bigeye tuna is mainly taken by longline (Fig. 1). And Japan, Korea and Taiwan are the three major longline nations whose average catches accounted for about 84% of the total catch during the *1985-1995* period (IPTP 1997).

Based on the historical longline fishery catch and effort data, there are several studies regarding the stock status of the Indian bigeye tuna, such as the production model analysis (e.g., Miyabe 1988; Chang and Hsu 1993) and virtual population analysis (Nishida and Takeuchi 1999). However, the latest production model analysis (Chang and Hsu 1993) resulted in underestimating maximum sustainable yield apparently because the data series used are in moderate exploitation stage for the stock; The result of virtual population analysis seemed using only some parts of fishery data and did not use abundance index derived from Taiwanese fishery that is taking account large part of the catches, especially, of the recent years (Fig. 2).

Traditionally, the standardized catch per unit effort is usually used as abundance index in the stock assessment, and the longline CPUEs derived from three major longline fishing nations were available for bigeye tuna in the Indian Ocean. However, since 1 970s, Taiwan fishermen have introduced super-cold freezers to target bigeye tuna, and the activity was significantly operated in the Indian Ocean from 1986. As the consequence, two main fishing types have been using for different targets in the Indian Ocean to direct different species. Those mixed fishing types in fishery data have resulted in the reliability of standardizing fishing effort, because the fishing efforts that exactly used for different targets were not easy to separate for Taiwaneselongline fishery. Even the GLM or GENMOD (O'Brien et al. 1997) is very difficult to define the factor that corresponds to different fishing types unless the number of hooks between floats was known.

Purse seine is the secondary fishery for bigeye tuna, although bigeye tuna is not the target species. The standardization of purse seine fishing effort is difficult, so the purse seine CPUE may not be available.

As usual, a multiplicative GLM model with the assumption that the error structure is a lognormal distribution and GENMOD model with the error structure that is Poisson distribution (Nelder and Wedderburn 1972; O'Brien et al. 1997; Okamoto and Miyabe, 1998) have been often used in standardizing catch per unit effort as an abundance index. In the present study, these- two models were used for adjusting Indian bigeye tuna CPUE caught by longline fishery.

The age-structured production model analysis (ASPM) has been used to asses~ the status of many tunas frequently in the Atlantic. For instance, western Atlantic bluefin tuna *(Thunnus alalunga)* (Restrepo 1997), southern Atlantic albacore (Punt 1992 ; Punt *et al*, 1992, 1995, 1996a, b, c) . northern Atlantic albacore (Punt 1996), Atlantic bigeye tuna (Miyabe 1996; 1998), Atlantic albacore (Hsu 1996; O'Brien eta!. 1997), Indian albacore (Hsu 1995), southern Africa Cape hakes *(Merluccius spp.)* (Punt 1994). Therefore, the objectives of this document are to (1) partition fishing efforts into deep and regular efforts for Taiwanese longline fishery, (2) use GLM and GENMOD to standardize three longline catch/effort series (i.e., Japan, Korea and

MATERIAL AND METHODS

1. Basic data

The time series catch/effort data were extracted from 1979 to 1996, from 1955 1995 and from 1975 to 1993 for Taiwanese, Japanese and Korean longline fisheri respectively. Only daily logbook data of Taiwanese longline fishery were used the. aggregated form of 5-degree square and by day. Japanese and Korean longli:

catch/effort data were provided by IPTP in the form of aggregating 5-degree squa and by month.

The information of the number of hooks between floats is one of the mc important factors in standardizing abundance index, this information was availal from 1995 for Taiwanese longline fishery. Thus, 1995 and 1996 daily logbook da were used to seek a possible rule to partition fishing efforts from different fishii types (Lin 1998). For partitioning fishing efforts, the rule was used to l979-19~ daily logbook data of Taiwanese longline fleets.

Standardization

The GLM and GENMOD procedure of SAS/STAT statistical package (Versi(6.11) were used to fit the CPUE and catch model, respectively.

The CPUE model with lognormal error structure is:

£n(CPUEqJk/mfl + *constant)* = *,u* + ~ + *M~* + *Ak* + *Boat*$_1$ ÷ *ALM,* + *YFT~* + **(1** mt *eractions* +

where *In:* natural logarithm operator; CPUE,jklmn **: nominal CPUE (catch in numb** per 1000 hooks, in year i , month **j,** subarea k, vessel type 1, effect of albacore CPUE and effect of yellowfin CPUEn); j.t : overall mean; Y, : effect of year i ; M, : effect month **j ;** A~: effect of subareas k ; Boat$_1$: effect of vessel type 1; ALBm **:** effect albacore CPUE m ; YFT~ : effect of yellowfin CPUE n ; interactions : two w~ interactions ; e~~fl : normal error term; and 10% of overall mean is used for constant

There is a close relationship between vessels' capacity and catchability (Robs 1966; Punt ez' *a!.* 1996a). The vessels' capacity was divided into five categories I GRT (gross registered tonnage) and included in the model.

By-catch component may influence a trend of standardized CPUE sen (Okamoto and Miyabe 1993; Miyabe 199&; Wu *et a!.* 1996; Scott and Bertolii 1998). Thus, CPUE for other major species (ALB: albacore; YFT: yellowfin) we also included in the model, in which zero CPUE was set as class one, and others we classified into four levels.

Due to lack of related information of by-catch and vessels' capacity in ti extracted data of Japanese and Korean longline fishery, these effects do n incorporate into the processing of CPUE standardization for both Japanese at Korean data.

The catch model with Poisson distribution by GENMOD procedure is:

E(C) = *He* */J+Y,* ***+M~*** +4 ***+IJoai***$_1$ ***+ALBm*** +YFT,, **+int** *eraclwns* (2)

where E(C): expectation of catch in number, which the Poisson error structure was assumed; and H: number of hooks used.

The goodness of fit was tested by mean square total. In addition, the effects that incorporate into the best-fitted GENMOD model were determined by likelihood ratio chi-square.

Considering the geographical distribution of nominal CPUE (Fig. 3) and fishing effort (Fig. 4) of Indian bigeye tuna caught by Taiwanese longline fishery during 1979

1996 periods and the fishing area division of Indian bigeye tuna by other scientists (Suda *et a!.* 1969; Kume *et a.*, 1971; Koido 1985; Okamoto and Miyabe 1993; Hsu and Chang 1993; Mohri *et a!.* 1997). The main fishing ground in the Indian Ocean was divided into five subareas (Fig. 5).

FITTING THE ASPM MODEL

3.1. Data used

Catch in weight; annual abundance indices and the age specific selectivity are required for ASPM analysis.

(1) Catch in weight:

Catches in weight before 1977 were taken from Miyabe (1988). More recent data (from 1978 to 1995) were obtained from IPTP (1997). Those data for the entire fishery for the period 1952 to 1995 are given as Fig. 1.

(2) Annual abundance indices:

Annual CPUE series of Taiwanese, Japanese and Korean longline data, which depend on data availability from 1955 to 1995, which was standardized by GLM and GENMOD, were used.

(3) The age-specific selectivity:

Assuming that the age-specific selectivity of longline gear is a logistic curve. The age at *50%* selectivity was estimated from the length and growth curve (Azevedo 1983). And the age-specific selectivity was estimated from actual size measurement of Taiwanese longline fleets during the period 1980 to 1985 (Fig. 6).

PARAMETERS SPECIFICATION

Base case

The parameters used to ASPM were as given below:

1. It is assumed that the relationship between recruitment and spawning biomass

was followed the Beventon and Holt relationship.

2. The error terms were followed the lognormal error distribution.

3. Biological parameters:

(1) Natural mortality was assumed to be equal to 0.8 per year for age 1 and age 2,

0.4 per year for age 3 to age 8+.

bigeye tuna, and the length weight relationship (IPTP, 1985) for Indian bigeye tuna.

$= 338.53(1 - e^{\circ,\circ 4097\sim\sim \circ 5425\sim}$ (3)

$Wa = 2\sim 7X10\sim^{5}ta^{2}\bullet^{951}$ (4)

(3) Fecundity at age is given by:

0 $a<5$ $fa = 0.5$ $a=5$(~‘)

1 $a>5$

(4) It is assumed that fish are not to live beyond eight years old of their life, there is, the plus group was defined at age 8.

(5) The width parameter ô in age specific selectivity function was assumed to bI

0.5 per year.

$Sya= \underline{1}$ (6)

$1 + \exp(—(a - a_{50\sim})/5)$

where: Sya: the age specific selectivity of age a in year y

width parameter

RESULTS

CPUE standardization

Lin’s criteria (Lin 1998) for partitioning fishing efforts from different fishin types were adopted to separate the deep longline data. Then the GLM an GENMOD were applied for those fishery data. ANOVA results and goodness of *f* (Tables I and 2) for the final GLM model and GENMOD model were diagnosec The contribution of each factor was also evaluated by the sum of squares, and find that the effect of fishing subarea has the largest variability among all the facton indicating that abundance index of bigeye tuna in the Indian Ocean have apparer spatial trend. Fig. 7, showing the distribution of overall standardized residuals of th final GLM model for each period under each country, also indicates that th assumption of error structure is approximately fit a log-normal distribution.

The standardized CPUE derived from the two models, with the upper and lowe *95%* confidence limits, are illustrated Fig. 8 and Fig. 9 for GLM and GENMOI respectively. The estimated annual abundance index shows smaller fluctuation b GLM than by GENMOD. Visual Comparison could find larger fluctuation for nominal CPUE than for standardized CPUE. However, the overall trends were quite similar.

Fig. 10 compares the tendencies of standardized CPUE series obtained from the two general linear models. The correlation coefficient were larger than 0.78. It may indicate that the relative CPUE estimated in the present study has a similar trend and is valid for use.

The ASPM results

Briefly, the test runs of the ASPM were omitted. The fitting results of stochastic ASPM (Restrepo and Legault 1997) was shown in Fig. 11. The estimated MSY is nearly 116 thousands tons which is approximately equivalent to the current catch level (1995). The ratio of F/FMSY were also lower than 1, but abruptly approaching to 1, for entire data series. Those results give the Indian bigeye tuna stock a reasonable exploitable condition.

Table 3 lists the estimated eight quantities for the biomass in the middle of 1995 (B_{1995}), MSY, the biomass at MSY (BMSY), the depletion of 1995 (B_{1995}/K), the fraction between mature biomass of 1995 and the mature biomass of carry capacity (B~~t$_{1995}$/K~~t), the stock recruitment relationship related value (steepness), the ratio between the fishing mortality of 1995 and the corresponding value at MSY (F_{1995}/FMSY), and the replacement yield of 1996 (RY_{1996},). All those information show good condition for exploiting the stock, but recently, the increasing fishing mortality (catch and effort) abruptly also gives the stock a warning of decreasing stock biomass.

Fig. 12 and Fig. 13 show the point estimates of average fishing mortality and mid-year biomass for each age group. The fishing mortality of age 1 and age 2 fish increased abruptly from 1984. This result is pretty coincident with the major introduction of purse seine fleets after 1984. The tendency of average mid-year biomass of various age groups, obtained from the present study indicates that a very strong year-class occurred in 1973, and appeared in strong age 1 class in 1974.

DISCUSSION

Different fishing efforts have been partitioned using the criteria proposed by Lin (1998). The vertical distribution of bigeye tuna was not marked differences by depth by 25°S southward of the Indian Ocean (Mohri et al. 1997). The hook depth of deep longline gear is usually between lOOm - 250m which is similar to the reported previously by Mohri et a!. (1997) and Nakano et a!. (1997). The fishing efforts directed to bigeye tuna can be either deep or conventional deployments in the area of 25°S southward in the Indian Ocean.

The CPUE trends among three nations are different from 1979 to 1993. Reasons may be two folds: the discrepancies of data attributes and inconsistent catchability. These situations might result from the difference of fishing gear, fishing strategy, the variables that used in the standardization procedure and the geographical zone of higher fishing effort. For example, the fishing ground off west Australia and Cape Town of South Africa were the major operation area of Japanese longline vessels during the time period from 1955 to 1995. But in contrast, those areas were not the major operation zone of Taiwanese and Korean longline vessels.

The estimate of steepness was rare low (Table 4). The steepness can elucidate well the relationship between spawning stock biomass and recruitment. As the result, the Indian Ocean bigeye tuna stock has a very limited tolerance to the pressure of fishing. This is inconsistent with a concept that tuna species usually do not exhibit obvious relationship between spawning stock size and recruitment (Punt, 1996). It should be given much evidence for the relationship between spawning size and recruitment, when we obtain the CPUE series ofjuvenile and adult fish.

The stock status of Indian bigeye tuna fisheries has been reviewed critically in the past by several authors (Miyabe, 1988; Hsu and Chang, 1993; Nishida and Takeuchi. 1999). In the present study the ASPM results seem overoptimistic. It assesses the resource less depleted recently and has a higher MSY than the other authors referred by surplus production model (Miyabe 1988; Chang and Hsu 1993). Moreover, the growth equation used in the present study was not the ones for Indian bigeye tuna and this could be the reason that resulted in the overestimation of MSY.

The ratio of $B_{1\sim5}/K$ and $B\sim\ \sim$ are estimated larger than 0.9 and 0.8, respectively. The biomass in the middle of *1995* seems sustainable. Because when the ratio of $B\sim_{,j\sim mat}$ smaller than 0.2, the resource was nearly under recruitment overfishing (Francis, 1992; ICCAT, 1998).

Introduction of purse seine fishery in the past two decades, with marked by-catch ofjuvenile bigeye tuna, may lead to change the fishing pattern exerted on the stock of bigeye tuna. These changes may affect the jurisdiction of the assessing results. Conclusively, owing to the data of Indian bigeye tuna only limited from *1955* to *1995* and the intense fluctuation of CPUE series in recent years, the ASPM results may not reflect the real condition sufficiently. However, the results of ASPM analyses can be quite useful. When the data sets before 1955 and after 1,995 periods is made available, the assessment of bigeye tuna should be updated in future.

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Table 1 The results of ANOVA for each optimal CPIJE models used the GLM procedure in SAS/STAT.

I. Taiwanese Longline (1979-1996) R-square= 0.363

Source	DF	Sum of Squares	Mean Square	F value	Pr>F
Model	*156*	77626.63	497.61	652.35	0.0001
Error	177922	135717.07	0.76		
Corrected Total	178078	213343.70			
Source	DF	Type I SS	Mean Square	F value	Pr>F
Boat	4	1594.05	398.51	522.44	0.0001
Y	17	6057.60	356.33	467.14	0.0001
M	11	7093.44	644.86	845.39	0.0001
A	4	55804.49	13951.12	18289.61	0.0001
ALB	4	190.93	47.73	62.57	0.0001
“(FT	4	2057.41	514.35	674.30	0.0001
Y*A	68	2454.64	36.10	47.32	0.0001
M*A	44	2374.07	53.96	70.74	0.0001

IT -I. Japanese Longline (1955-1976) R-square= 0.346

Source	DF	Sum of Squares	Mean Square	F value	Pr>F
Model	164	3891.64	23.73	45.29	0.0001
Error	14044	7358.72	0.52		
Corrected Total	14208	11250.36			
Source	DF	Type I SS	Mean Square	F value	Pr>F
Y	21	545.27	- 25.97	49.55	0.0001
M	11	124.32	11.30	21.57	0.0001
A	4 ,	2477.36	619.34	1182.00	0.0001
M*A	44	337.77	7.68	*14.65*	0.0001
Y*A	84	406.92	4.84	9.25	0.0001

11-2. Japanese Longline (1977-1995) ‘ R-square= 0.274

Source	DF	Sum of Squares	Mean Square	F value	Pr>F
Model	33	1927.03	*58.39*	101.67	0.0001
Error	8876	5097.74	0.57		
Corrected Total	8909	7024.77			
Source	DF	Type ‘I SS	Mean Square	F value	Pr>F
Y	18	159.53	8.86	15.43	0.0001
M	11	92.16	8.38	14.59	0.0001
A	4	1675.34	418.84	729.26	0.0001

III - 1. Korean Longline (1975-1987) R-square 0.242

Source	DF	Sum of Squares	Mean Square	F value	Pr>F
Model	27	706.17	26.15	75.59	0.0001

Error	6377	2206.51	0.35
Corrected Total	6404 'I	2912.69	

Source	DF	Type I SS	Mean Square	F value	Pr>F
Y	12	194.85	16.24	46.93	0.0001
A	4	483.23	120.81	349.15	0.0001
M	11	28.09	2.55	7.38	0.0001

III - 2. Korean Longline (1988-199 1) R-square= 0.260

Source	DF	Sum of Squares	Mean Square	F value	Pr>F
Model	7	86.64	12.38	13.57	0.0001
Error	270	246.24	0.91		
Corrected Total	277	332.88			

Source	DF	Type I SS	Mean Square	F value	Pr>F
Y	**3**	**9.47**	3.16	3.46	0.0169
A	4	77.17	19.29	21.15	0.0001

III - 3. Korean Longline (1992-1993) R-square 0.199

Source	DF	Sum of Squares	Mean Square	F value	Pr>F
Model	15	42.35	2.82	8.65	0.0001
Error	*522*	170.31	0.33		
Corrected Total	537	212.66			

Source	DF	Type I SS	Mean Square	F value	Pr>F
Y	1	0.07	0.07	0.20	0.653 1
A	3	30.47	10.16	31.13	0.0001
M	11	11.82	1.07	3.29	0.0002

Table 2 Goodness of fit for the optimal catch models used the GENMOD procedure in SAS/STAT.

I. Taiwanese Longline (1979-1996)

Criterion	DF	Value	ValueTDF
Deviance	177922	1651834.89	9.28
Scaled Deviance	177922	177922.00	1.00
Person chi-square	177922	2031461.67	11.42
ScaledPersonX^2	177922	218812.26	1.23
Log Likelihood		426125.67	

LR Statistics For Type 1 Analysis

Source	Deviance	NDF	DDF	F	Pr>F	Chi Square	Pr>Chi
INTERCEPT	2334743.90	0	177922				
Boat	2314594.66	4	177922	542.58	0.0001	2170.31	0.0001
Y	2240605.96	17	177922	468.79	0.0001	7969.45	0.0001
M	2187403.83	11	177922	520.95	0.0001	5730.49	0.0001
A	1725071.11	4	177922	12449.66	0.0001	49798.66	0.0001
M*A	1693183.92	44	177922	78.06	0.0001	3434.62	0.0001
Y*A	1663057.02	68	177922	47.72	0.0001	3245.02	0.0001
ALB	1660424.13	4	177922	70.90	0.0001	283.59	0.0001
YFT	1651834.89	4	177922	231.29	0.0001	925.16	0.0001

11-1. Japanese Longline (1955-1976)

Criterion	DE	Value	Value/DF
Deviance	14044	2825040.87	201.16
Scaled Deviance	14044	14044.00	1.00
Person chi-square	14044	3940429.68	280.58
ScaledPersonX^2	14044	19588.88	1.39
Log Likelihood		168398.11	

LR Statistics For Type 1 Analysis

Source	Deviance	NDF	DDF	F	Pr>F	Chi Square	Pr>Chi
INTERCEPT	5327782.91	0	14044				
Y	4810431.78	21	14044	122.47	0.0001	2571.88	0.0001
M	4781272.72	11	14044	13.18	0.0001	144.96	0.0001
A	3298885.48	4	14044	1842.33	0.0001	7369.33	0.0001
M*A	3135288.17	44	14044	18.48	0.0001	813.28	0.0001
Y*A	2825040.87	84	14044	18.36	0.0001	1542.32	0.0001

11-2.Japanese Longline (1977-1 995)

Criterion	DF	Value	Value/DF
Deviance	8762	2561473.19	292.34
Scaled Deviance	8762	8762.00	1.00
Person chi-square	8762	3680232.67	420.02
ScaledPersonX^2	8762	12588.93	1.44
Log Likelihood		110008.75	

13

LR Statistics For Type I Analysis

Source	Deviance	NDF	DDE	F	Pr>F	Chi Square	Pr>Chi
INTERCEPT	5983601.14	0	8762				
Y	5792155.11	18	8762	36.38	0.0001	654.88	0.0001
M	4950855.10	11	8762	261.62	0.0001	2877.82	0.0001
A	3181073.78	4	8762	1513.47	0.0001	6053.87	0.0001
M*A	2921583.30	42	8762	21.13	0.0001	887.64	0.0001
Y*A	2561473.19	72	8762	17.11	0.0001	1231.82	0.0001

ifi- 1. Korean Longline (1975-1987)

Criterion	DF	Value	ValueTDF
Deviance	6377	656167.85	102.90
Scaled Deviance	6377	6377.00	1.00
Person chi-square	6377	741874.92	116.34
Scaled Person X^2	6377	7209.95	1.13
Log Likelihood		229542.77	

LR Statistics For Type 1 Analysis

Source	Deviance	NDF	DDF	F	Pr>F	Chi Square	Pr>Chi
INTERCEPT	1100441.66	0	6377				
Y	882400.91	12	6377	159.37	0.0001	1912.47	0.0001
A	738539.98	4	6377	338.82	0.0001	1355.28	0.0001
M	695215.20	11	6377	37.74	0.0001	415.15	0.0001

ifi -2. Korean Longline (1 988-1991)

Criterion	DF	Value	Value/DF
Deviance	270	118427.09	438.62
Scaled Deviance	270	270.00	1.00
Person chi-square	270	101401.76	*375.56*
Scaled PersonX^2	270	231.18	0.86
Log Likelihood		4390.34	

LR Statistics For Type 1 Analysis

Source	Deviance	NDF	DDF	F	Pr>F	Chi Square	Pr>Chi
INTERCEPT	158594.64	0	270				
Y	156733.74	3	270	1.41	0.2389	4.24	0.2364
A	118427.09	4	270	21.83	0.0001	87.33	0.0001

ifi -3. Korean Longline (1992-1993)

Criterion	DF	Value	Value/DF
Deviance	522	26678.90	51.11
Scaled Deviance	522	522.00	1.00
Person chi-square	522	28731.00	*55.04*
Scaled Person X^2	522	562.15	1.08
Log Likelihood		25476.63	

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LR Statistics For Type1 Analysis

Source	Deviance	NDF	DDF	F	Pr>F	Chi Square	Pr>Chi
INTERCEPT	45180.80	0	522				
Y	44063.54	1	522	21.86	0.0001	21.86	0.0001
A	39233.02	3	522	31.50	0.0001	94.51	0.0001
M	26678.90	11	522	22.33	0.0001	245.63	0.0001

Table 3 Summary of stock status estimated by stochastic age-structured Production model for bigeye tuna in the Indian Ocean

Categories	Estimate
Maximum sustainable yield (MSY)	115890 mt
Current (1996) yield	116490 mt
Relative biomass (B 1995/BM5Y)	>39
B_{1995} 1K	1.21
B 1995 irs.. matn,mat	
Relative of fishing mortality (F1995/FMSy)	0.42
Replacement yield 1996	121.83
Steepness	0.22

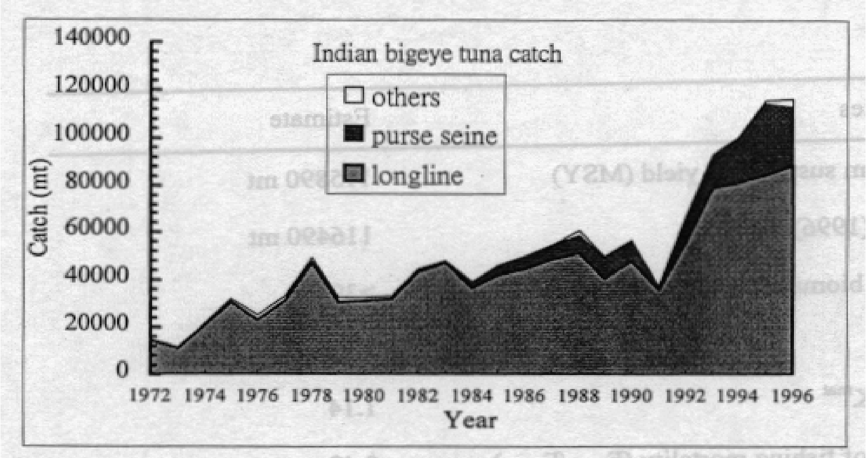


Fig. 1 Catches of bigeye tuna by gear in the Indian Ocean for 1972-1996

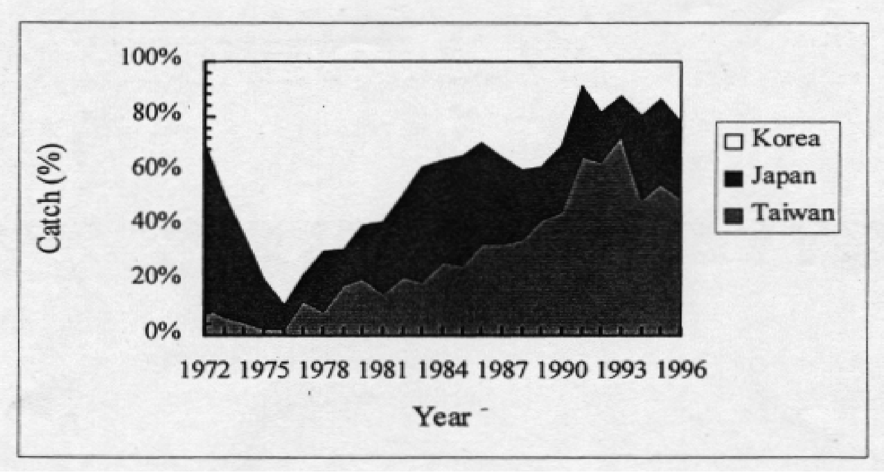


Fig. 2 Catches of bigeye tuna for longline gear by countries in the Indian Ocean

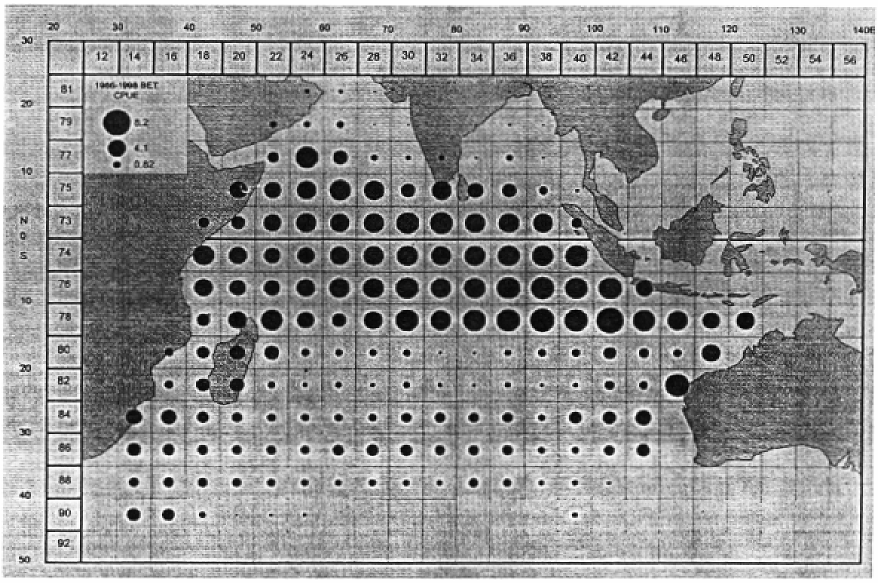


Fig. 3 Catch per unit effort distribution of bigeye tuna in the Indian Ocean (1986-1998)

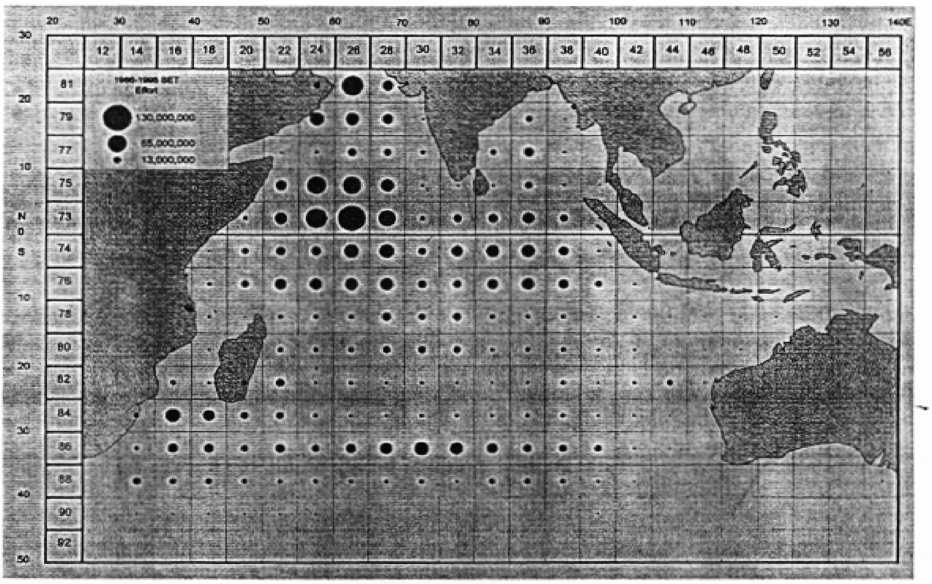


Fig. 4 Fishing effort distribution of Taiwanese longline fleets in the Indian Ocean

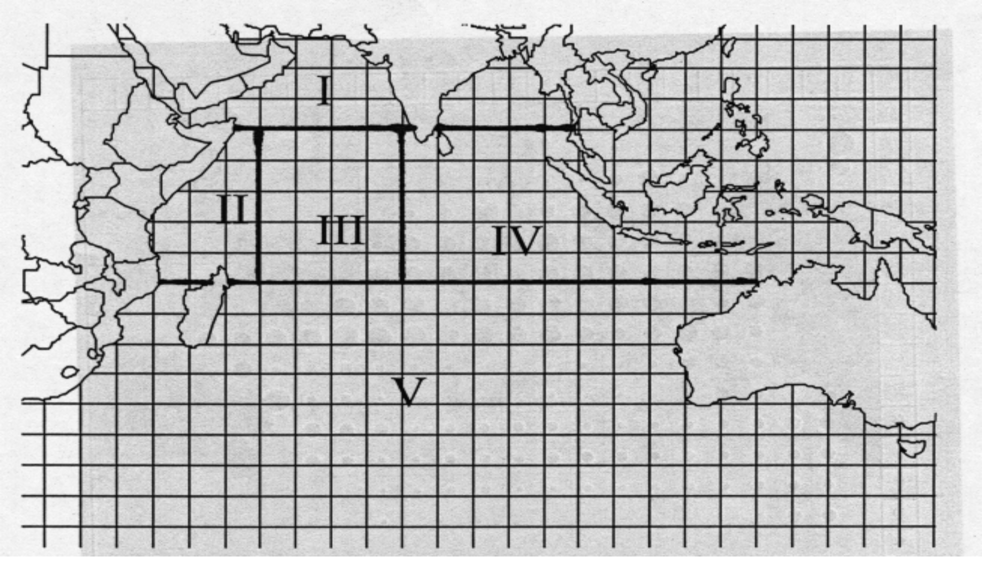


Figure 5. Subareas used h~ the standardization of CPUE for bigeye tima h~ the Indian Oceam

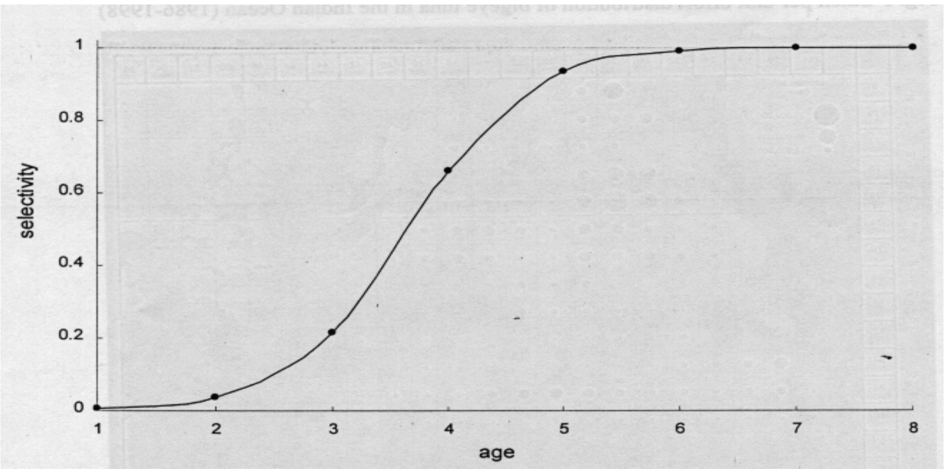
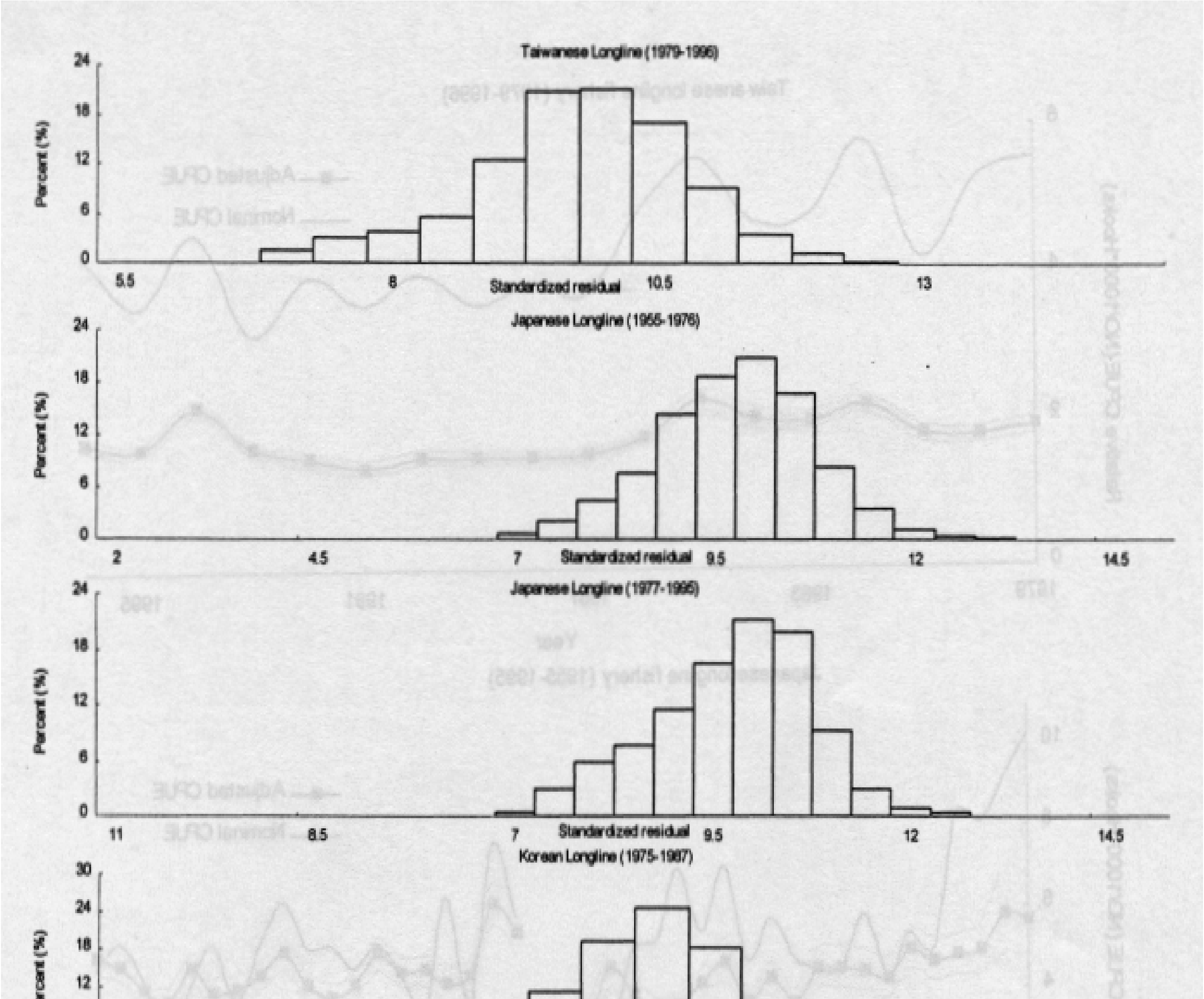


Figure 6. Assun~d input selectivities at age tbr longline fishery.



Distribution of standardized residuals of adjusted CPUE from optimal CPUE and deal with GLM procedure with constant equal to (10% Overall Mean) added.

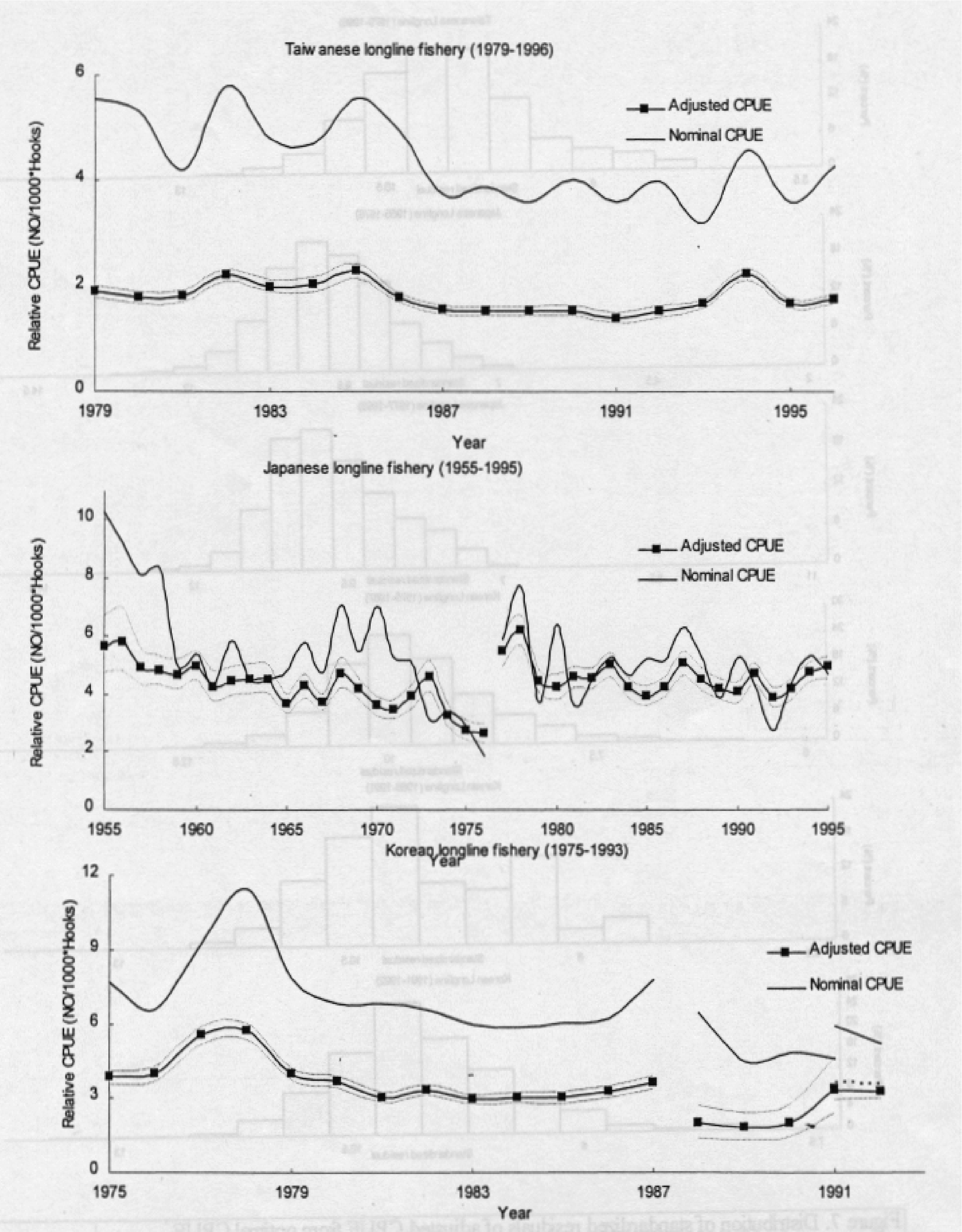


*Figure 8. Trend of annual adjusted CPUE (No.1 000 *hooks) by GLM procedure (constant equal to 0.1 *Mean) of bigeye tuna in the Indian Ocean of Taiwanese longline fishery (upper and lower broken line indicate 95% confidence limits*

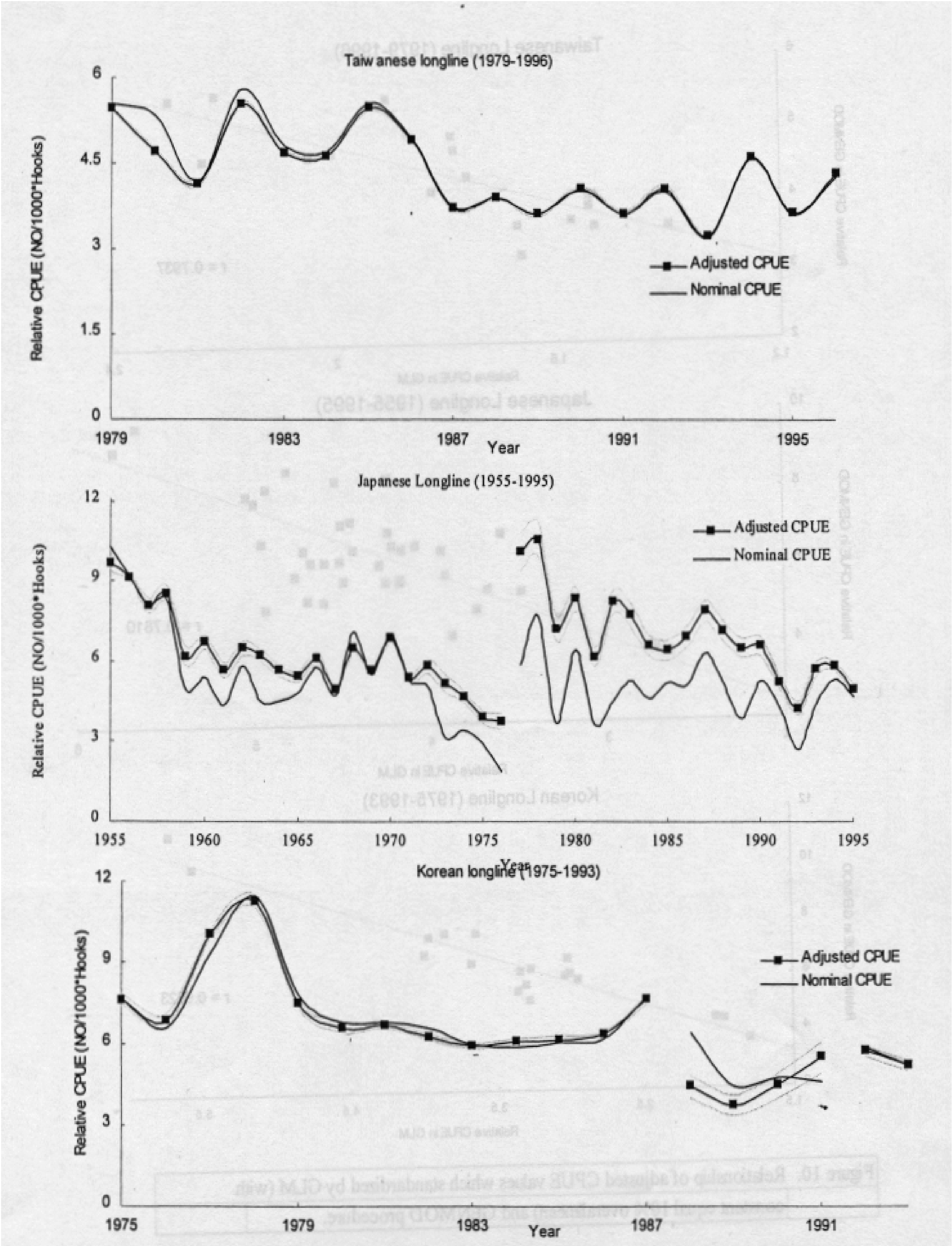


*Figure 9.Trends of annual adjusted CPUE (No.1 000*Hooks) by GENMOD procedure of bigeye tuna in the Indian Ocean of Taiwanese Japanese and Korean longline………95% limits*

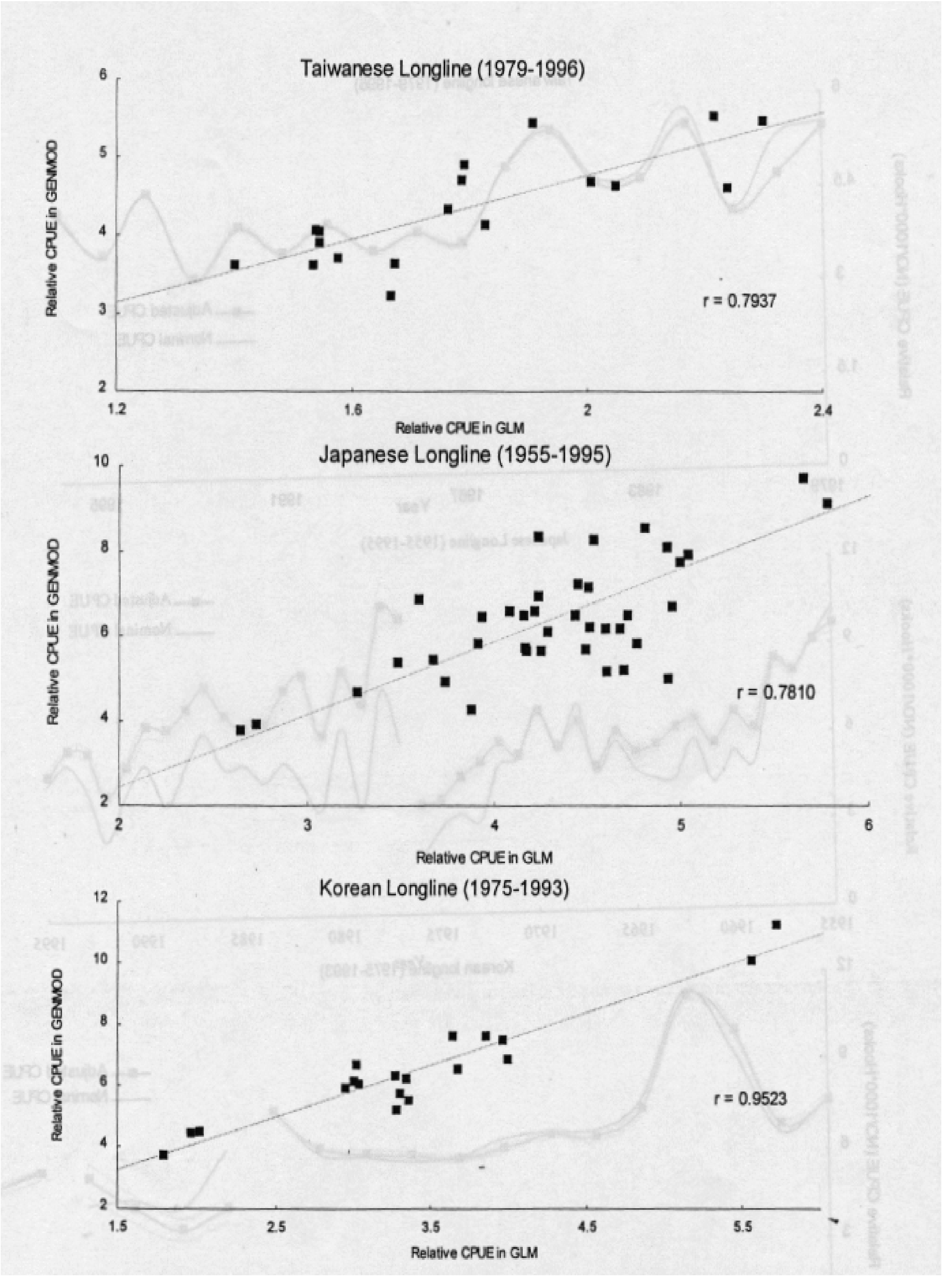


Figure 10. Relationship of adjusted CPUE values which standardized by GLM (with jconstant equal 10% overallmean) and GENMOD procedure.

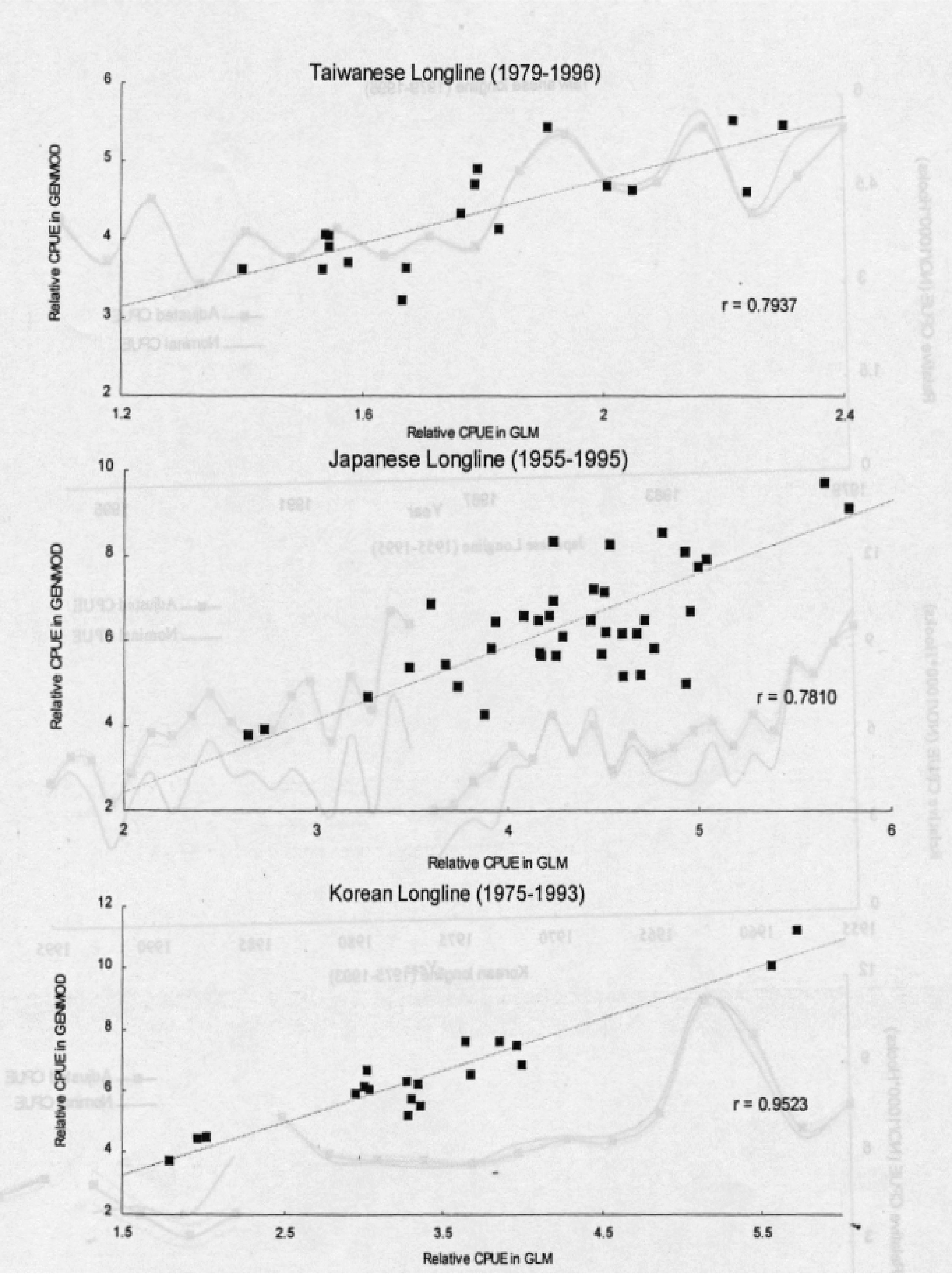
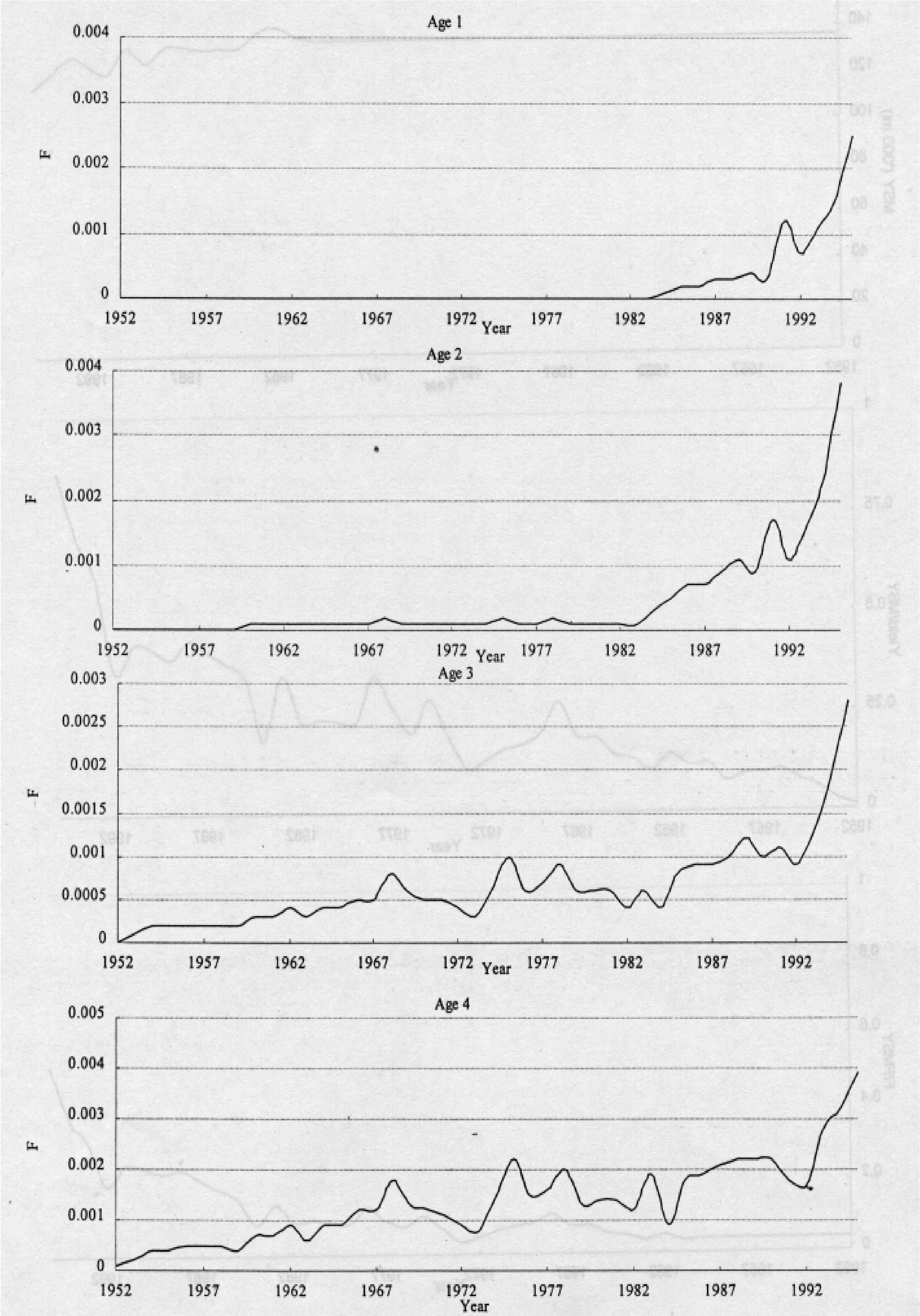
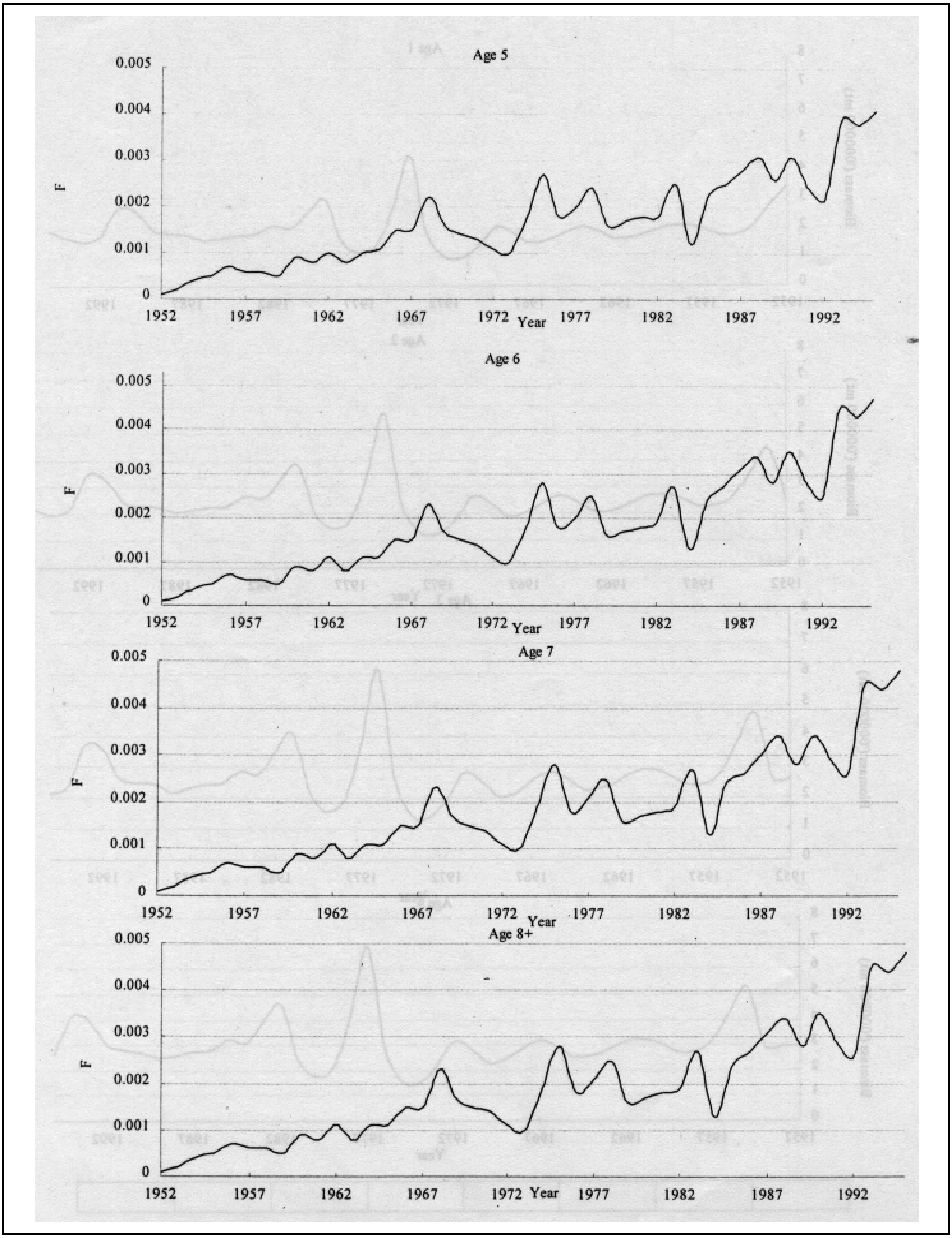
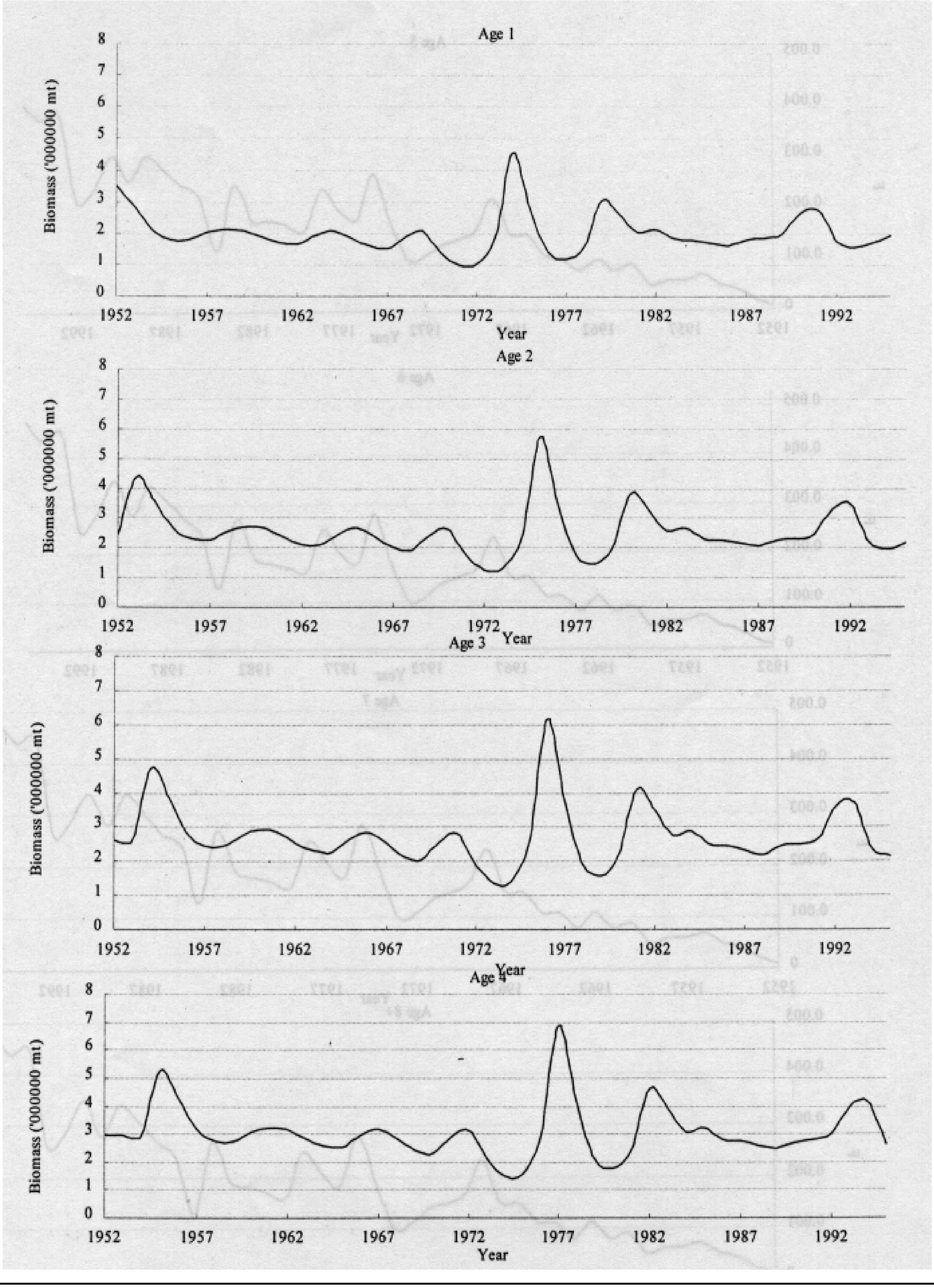


Figure 10. Relationship of adjusted CPUE values which standardized by GLM (with 1 constant equal 10% overall mean) and GENMOD procedure


Age 1
0.004
0.003
0.002
0.001
0
F
1952
1957
1962
1967
1972
Year
1977
1982
1987
1992
Age 2
0.004
0.003
0.002
0.001
0
F
1952
1957
1962
1967
1972
Year
1977
1982
1987
1992
Age 3
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
F
1952
1957
1962
1967
1972
Year
1977
1982
1987
1992
Age 4
0.005
0.004
0.003
0.002
0.001
0
F
1952
1957
1962
1967
1972
Year
1977
1982
1987
1992


Age 5
F
0.005
0.004
0.003
0.002
0.001
0
1952
1957
1962
1967
1972
Year
1977
1982
1987
1992
Age 6
F
0.005
0.004
0.003
0.002
0.001
0
1952
1957
1962
1967
1972
Year
1977
1982
1987
1992
Age 7
F
0.005
0.004
0.003
0.002
0.001
0
1952
1957
1962
1967
1972
Year
1977
1982
1987
1992
Age 8+
F
0.005
0.004
0.003
0.002
0.001
0
1952
1957
1962
1967
1972
Year
1977
1982
1987
1992


Age 1
Biomass ('000000 mt)
0
1
2
3
4
5
6
7
8
1952
1957
1962
1967
1972
1977
1982
1987
1992
Year
Age 2
Biomass ('000000 mt)
0
1
2
3
4
5
6
7
8
1952
1957
1962
1967
1972
1977
1982
1987
1992
Year
Age 3
Biomass ('000000 mt)
0
1
2
3
4
5
6
7
8
1952
1957
1962
1967
1972
1977
1982
1987
1992
Year
Age 4
Biomass ('000000 mt)
0
1
2
3
4
5
6
7
8
1952
1957
1962
1967
1972
1977
1982
1987
1992
Year

Continue