Col.Vol.Sci.Pap. ICCAT, 47 : 245-254 (1998)

THE CPUE TREND FOR ATLANTIC BLUE MARLIN CAUGHT BY JAPANESE LONGLINE FISHERY

Koji Uosaki[1]

SUMMARY

*CPUEs of Atlantic blue marlin (*Makaira nigrica*) caught by Japanese longline fishery for 1956-1995 were standardized using a General Linear Model (GLM). The GLM was applied to two hypotheses on the stock structure, one total Atlantic stock and separate north and south Atlantic stocks. Standardized CPUEs under both hypotheses declined rapidly in the 1960s and then continued to decrease gradually until the 1990s.*

RÉSUMÉ

*Les CPUE des makaires bleus de l'Atlantique (*Makaira nigrica*) capturés par les palangriers japonais entre 1956 et 1995 ont été standardisées avec le Modèle Linéaire Généralisé (GLM). Ce modèle a été appliqué à trois types de stock, dans l'Atlantique Nord et l'Atlantique Sud. Les CPUE standardisées de l'ensemble des stocks indiquent un déclin rapide dans les années soixante, suivi d'un déclin progressif jusqu'aux années quatre-vingt-dix.*

RESUMEN

*Se estandarizaron las CPUE de ejemplares de aguja azul Atlántica (*Makaira nigrica*) capturados por la pesquería de palangre de Japón, 1956-1995, empleando el Modelo Lineal Generalizado (GLM). Se aplicó el GLM a tres categorías de stock, es decir, norte y sur del Atlántico. Las CPUE estandarizadas para todos los stocks declinaron rápidamente en los años 60, y continuaron disminuyendo gradualmente hasta la década de los 90.*

1. INTRODUCTION

The Japanese longline fishery has exploited Atlantic blue marlin as a by-catch since the fishery commenced in 1956. The distribution of the effort of the fishery has changed drastically mainly due to the change of target species. Throughout the history, the main fishing grounds of this fishery have not covered the area where the blue marlin is primarily distributed, except for a short period in the 1960s (Uozumi and Nakano, 1994). The CPUE standardization of Atlantic blue marlin was carried out by Kikawa and Honma (1980, 1983) and Watanabe *et al.* (1989) using the Honma method, and Nakano *et al.* (1994) using the GLM and the Honma methods. In this report the standardized CPUE was updated using the GLM for the 1956-1995 period.

2. DATA AND METHODS

The data for this report were obtained from Japanese longline fishery statistics, compiled at the National Research Institute of Far Seas Fisheries, based on the logbooks. Two kinds of data sets were used in this report: one using Task II catch and effort data for 1956-1975 (Dataset I), and the other using the same data set as Task II but additionally including gear configuration information, namely, number of hooks per basket, for 1975-1995 (Dataset II). The data in 1995 are preliminary. The CPUE used was the number of blue marlin caught per 1,000 hooks. Observations with less than 3,000 hooks were excluded from this analysis. Observations within the EEZ were also excluded.

A GLM was used to standardize CPUE of blue marlin with the main effects of year, fishing season, area, and gear configuration. Quarters were used for fishing season. Twelve subareas were defined for Dataset I and thirteen for Dataset II based on the spatial distribution pattern of nominal CPUE of blue marlin (Figure 1). The gear configuration was categorized into four levels: 4-8, 9-11, 12-15 and, 15-20 hooks per basket, the first three levels were according to Uozumi

[1] National Research Institute of Far Seas Fisheries, 7-1, Orido 5 chome, Shimizu-shi, 424 Japan

and Nakano (1994), and a fourth was established because the gear with 16 or more hooks per basket was introduced in the late 1980s and has become more common in recent years. Two stock hypotheses were assumed; total Atlantic and separate north and south Atlantic, and the GLM applied. The GLMs used were :

$$\ln(\text{CPUE}+0.001)=\mu+\text{Y}+\text{Q}+\text{A}+\text{Interactions}+\text{e}$$ for Dataset I (1956-75)

$$\ln(\text{CPUE}+0.001)=\mu+\text{Y}+\text{Q}+\text{A}+\text{G}+\text{Interactions}+\text{e}$$ for Dataset II (1975-1995)

where μ : overall mean; Y : effect of year; Q : effect of quarter
A : effect of subarea; G : effect of gear; e : error term
Interactions : any combination of two way interaction

In order to include observations for which there was fishing effort but no catch of blue marlin, the natural logarithm of CPUE+0.001, instead of CPUE, was used. The constant, 0.001, was selected based on the examination of the distribution of log transformed nominal catch rates of blue marlin, being relatively small when compared to the observed values of nominal CPUE of blue marlin (Figure 2). A fit of the model was attempted with all combinations of two-way interactions except for the interactions which had a lack of observations. Model selection was made using Akaike's Information Criterion (AIC):

$$\text{AIC}=\text{X}\ln(\text{MSE}) + 2\text{ Y}$$

where X is the number of parameters estimated, MSE is mean square error and Y is the number of observations. Analyses were conducted using SAS Version 6.11.

Standardized CPUE weighted by area is :

$$std\ CPUE_i=\exp\left(\mu+P_{Y_i}+\frac{1}{4}\sum_j PQ_j+\frac{A_k}{\sum_k A_k}\sum_k PA_k+\frac{1}{4}\sum_l PG_l+\frac{1}{4}\sum_j PYQ_{ij}\cdots\right)$$

Relative standardized CPUE, which is adjusted in the first year, is :

$$relative\ CPUE_i=\frac{std\ CPUE_i}{std\ CPUE_1}=\frac{\exp\left(P_{Y_i}+\frac{1}{4}\sum_j P_{YQ_{ij}}+\frac{A_k}{\sum_k A_k}\sum_k P_{YA_{ik}}+\frac{1}{4}\sum_l P_{YG_{il}}\right)}{\exp\left(P_{Y_1}+\frac{1}{4}\sum_j P_{YQ_{1j}}+\frac{A_k}{\sum_k A_k}\sum_k P_{YA_{1k}}+\frac{1}{4}\sum_l P_{YG_{1l}}\right)}$$

where
CPUE_i: standardized CPUE in i year
A_k : area which excludes land and adjusted latitude in area k
μ : estimated intercept
PY_i : estimated parameter for year term in i year
PQ_j : estimated parameter for quarter term in j quarter
PA_k : estimated parameter for area term in k area
PG_l : estimated parameter for gear term in l gear
PYQ_{ij} : estimated parameter for interaction term between year and quarter
PYA_{ik} : estimated parameter for interaction term between year and area
PYG_{il} : estimated parameter for interaction term between year and gear

3. RESULTS AND DISCUSSION

The summary of ANOVA for the tested model with AIC is shown in Table 1. The final model chosen for each stock and period is:

Total Atlantic	1956-1975	$\ln(CPUE+0.001) = \mu+Y+Q+A$	$+Q*A$
	1975-1995	$\ln(CPUE+0.001) = \mu+Y+Q+A+G$	$+Y*Q+Q*A+Q*G+A*G$
North Atlantic	1956-1975	$\ln(CPUE+0.001) = \mu+Y+Q+A$	$+Q*A$
	1975-1995	$\ln(CPUE+0.001) = \mu+Y+Q+A+G$	$+Y*A+Q*A+Q*G$
South Atlantic	1956-1975	$\ln(CPUE+0.001) = \mu+Y+Q+A$	$+Q*A$
	1975-1995	$\ln(CPUE+0.001) = \mu+Y+Q+A+G$	$+Y*Q+Q*A$

The results of the model for the total Atlantic, 1956-75 (Table 2), shows that the effect of quarter was not significant ($P=0.1071$), though the quarter*subarea interaction was significant ($P<0.0001$). The F values for the effect of subarea were the largest among the effects. The F value for the effect of gear in the south Atlantic was considerably higher than that in the north Atlantic. The R squares ranged from 0.56 to 0.65 for the period 1956-1975, and from 0.49 to 0.55 for the period 1975-1995. The distribution of the standardized residuals is nearly normal, though the distribution of standardized residuals is negatively skewed on the negative side for all cases in both periods.

The relative CPUEs and the standardized CPUEs which were adjusted to 1.0 in 1975, for 1956-1995, are shown in Table 3. The relative CPUEs for 1960-1995 and those for 1975-1995 are shown in Figure 4.a and Figure 4.b. For both stock hypotheses the relative CPUEs rapidly declined from about 10 to 1 between the early 1960s and late 1970s. After that, for the total and south Atlantic stocks, it continued to decline to about 0.5 in recent years. In the 1980s, the rate of decrease of the CPUE for the north Atlantic was less than that for the south Atlantic.

On the Japanese market, the price of blue marlin has gradually declined since 1976. Furthermore, the difference between the price of bigeye and that of blue marlin increased, with bigeye becoming more valuable (Anonymous 1968-1994). Hence, there is the possibility that Japanese longline fishermen may tend to discard blue marlin in recent decades; thus the logbooks may be under-reporting blue marlin catches.

4. LITERATURE CITED

ANONYMOUS. 1968-1994. Annual statistics of fishery products marketing. Japan, Ministry of Agriculture, Forestry, and Fisheries, Statistics and Information Department.

ICCAT. 1997. Report of the bluefin tuna methodology session. Inter. Comm. Conser. Atl. Tunas, *Biennial Report* 1995-96 (Part I),

KIKAWA, S. and M. Honma. 1980. Recent trends in catch, effort and size for white and blue marlins based on data from the Atlantic fishery. Inter. Comm. Conser. Atl. Tunas, *Coll. Vol. Sci. Pap*; IX (3); 641-645.

KIKAWA, S. and M. Honma. 1983. Catch and overall fishing intensity of the Atlantic billfishes, 1956-1980. Inter. Comm. Conser. Atl. Tunas, *Coll. Vol. Sci. Pap*; XVIII (3); 650-656.

NAKANO, H., Y. Uozumi and M. Honma. 1994. The CPUE trend for Atlantic blue marlin caught by Japanese longline fishery. Inter. Comm. Conser. Atl. Tunas, *Coll. Vol. Sci. Pap*; XLI; 408-424.

UOZUMI, Y. and H. Nakano. 1994. A historical review of Japanese longline fishery and billfish catches in the Atlantic Ocean. Inter. Comm. Conser. Atl. Tunas, *Coll. Vol. Sci. Pap*; XLI; 233-243.

WATANABE, Y. H. Nakano and Y. Nisikawa. 1989. Catch trend of Atlantic white and blue marlins by Japanese tuna longline fishery. Inter. Comm. Conser. Atl. Tunas, *Coll. Vol. Sci. Pap*; XXX(2); 351-354.

Table 1. Summary of ANOVA for the tested model with AIC. Effect of the model, Y, Q, A, and G indicate year, quarter, area, and number of hooks per basket, respectively.

Total Atlantic 1956-75 Obs.=7245

Model	# Par	R-sq.	C.V.	MSE	F	AIC
Y Q A	36	0.568	-68.94	4.034	287.69	10176.31
YQ	116	0.580	-68.28	3.957	110.95	10197.37
QA	84	0.607	-65.92	3.687	168.10	**9622.29**
YQ QA	164	0.617	-65.31	3.621	94.17	9649.58

Total Atlantic1975-95 Obs.=20964

Model	# Par	R-sq.	C.V.	MSE	F	AIC
Y Q A G	42	0.475	-44.97	3.680	498.34	27399.96
YQ	126	0.482	-44.73	3.642	198.10	27349.93
QA	94	0.496	-44.12	3.542	277.35	26703.76
QG	58	0.479	-44.81	3.655	408.94	27288.22
AG	94	0.480	-44.79	3.652	260.60	27340.78
YQ QA	178	0.502	-43.91	3.509	156.53	26674.68
YQ QG	142	0.485	-44.62	3.624	183.41	27277.01
YQ AG	178	0.487	-44.56	3.614	147.47	27292.26
QA QG	146	0.498	-44.04	3.530	249.19	26732.03
QA AG	110	0.500	-43.96	3.518	189.56	26588.64
QG AG	146	0.484	-44.63	3.625	236.00	27291.47
YQ QA QG	194	0.504	-43.83	3.496	147.85	26627.12
YQ QA AG	230	0.506	-43.76	3.486	125.26	26636.79
YQ QG AG	194	0.490	-44.44	3.595	139.78	27211.97
QA QG AG	198	0.502	-43.87	3.503	176.77	26677.04
YQ QA QG AG	246	0.508	-43.67	3.471	120.03	**26578.82**

North Atlantic 1956-75 Obs.=3355

Model	# Par	R-sq.	C.V.	MSE	F	AIC
Y Q A	30	0.528	-68.60	4.064	138.05	4764.54
YQ	110	0.547	-67.78	3.969	48.78	4844.70
QA	54	0.560	-66.38	3.806	100.49	**4592.50**
YQ QA	134	0.576	-65.76	3.735	46.02	4689.16

North Atlantic 1975-95 Obs.=8320

Model	# Par	R-sq.	C.V.	MSE	F	AIC
Y Q A G	35	0.506	-40.24	3.450	273.77	10373.14
YQ	119	0.517	-39.94	3.399	96.70	10416.86
YA	161	0.534	-39.31	3.292	71.63	10235.12
QA	59	0.519	-39.75	3.366	193.89	10216.69
QG	51	0.516	-39.84	3.382	220.78	10240.39
AG	59	0.513	-39.98	3.406	189.53	10314.31
YQ YA	245	0.543	-39.08	3.254	50.56	10306.41
YQ QA	143	0.528	-39.50	3.324	86.77	10279.75
YQ QG	135	0.523	-39.69	3.356	90.56	10343.51
YQ AG	143	0.524	-39.69	3.356	85.19	10359.95
YA QA	185	0.545	-38.87	3.219	67.16	10096.73
YA QG	177	0.543	-38.94	3.230	69.54	10110.08
YA AG	185	0.537	-39.22	3.277	64.98	10245.03
QA QG	75	0.529	-39.35	3.300	168.63	10082.59
QA AG	83	0.526	-39.49	3.323	150.12	10157.37
QG AG	75	0.523	-39.59	3.340	164.77	10183.99
YQ YA QA	269	0.553	-38.70	3.190	48.67	10190.60
YQ YA QG	261	0.549	-38.84	3.214	49.44	10235.21
YQ YA AG	269	0.546	-38.98	3.237	47.41	10310.77
YQ QA QG	159	0.535	-39.23	3.279	82.12	10198.87
YQ QA AG	167	0.535	-39.26	3.284	77.89	10226.94
YQ QG AG	159	0.530	-39.43	3.313	80.58	10283.07
YA QA QG	201	0.554	-38.53	3.164	65.35	**9983.99**
YA QA AG	209	0.548	-38.78	3.204	61.52	10105.52
YA QG AG	201	0.547	-38.84	3.214	63.51	10114.73
QA QG AG	99	0.534	-39.16	3.267	185.21	10048.01
YQ YA QA QG	385	0.559	-38.47	3.153	47.69	10323.14
YQ YA QA AG	393	0.556	-38.60	3.174	45.86	10395.63
YQ YA QG AG	385	0.553	-38.72	3.195	46.55	10434.62
YQ QA QG AG	183	0.541	-39.03	3.246	74.16	10161.92
YA QA QG AG	225	0.556	-38.45	3.151	60.12	9997.96
YQ YA QA QG AG	409	0.561	-38.38	3.138	45.01	10333.28

South Atlantic 1956-75 Obs.=3890

Model	# Par	R-sq.	C.V.	MSE	F	AIC
Y Q A	30	0.636	-66.11	3.653	249.41	5099.42
YQ	110	0.651	-65.16	3.549	85.56	5146.80
QA	54	0.646	-65.26	3.560	167.30	**5046.84**
YA QA	134	0.660	-64.40	3.467	75.24	5104.22

South Atlantic 1975-95 Obs.=12644

Model	# Par	R-sq.	C.V.	MSE	F	AIC
Y Q A G	36	0.459	-47.89	3.736	334.91	16735.81
YQ	120	0.469	-47.58	3.688	120.40	16742.19
QA	64	0.476	-47.17	3.624	229.03	16409.16
QG	52	0.461	-47.83	3.726	263.10	16734.81
AG	64	0.461	-47.84	3.728	215.69	16764.96
YQ QA	148	0.487	-46.81	3.570	107.99	16385.44
YQ QG	136	0.471	-47.50	3.675	110.59	16729.47
YQ AG	148	0.471	-47.54	3.682	101.24	16775.90
QA QG	80	0.477	-47.14	3.620	174.72	**16426.59**
QA AG	92	0.478	-47.14	3.620	169.13	16448.95
QG AG	80	0.463	-47.78	3.718	183.93	16765.46
YQ QA QG	200	0.488	-46.75	3.561	100.42	16457.68
YQ QA AG	176	0.488	-46.79	3.566	93.15	16428.11
YQ QG AG	200	0.473	-47.46	3.669	94.35	16836.21
QA QG AG	108	0.479	-47.09	3.612	150.17	16452.75
YQ QA QG AG	264	0.490	-46.71	3.554	87.67	16563.14

Table 2. Analysis of variance for the final models.

Total Atlantic 1956-75

Source	DF	Sum of Sq.s	Mean Sq.	F Value	Pr > F
Model	66	40911.41	619.87	168.10	0.0001
Error	7178	26468.64	3.69		
Corr. Tot.	7244	67380.05			

R-Sq.= 0.607 C.V.= -65.92

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	19	2978.43	156.76	42.51	0.0001
Q	3	22.48	7.49	2.03	0.1071
A	11	14066.85	1278.80	346.80	0.0001
Q*A	33	2617.65	79.32	21.51	0.0001

Total Atlantic 1975-95

Source	DF	Sum of Sq.s	Mean Sq.	F Value	Pr > F
Model	179	74568.51	416.58	120.03	0.0001
Error	20784	72135.48	3.47		
Corr. Tot.	20963	146703.99			

R-Sq.= 0.508 C.V.= -43.67

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	20	864.64	43.23	12.46	0.0001
Q	3	190.09	63.36	18.26	0.0001
A	12	16397.32	1366.44	393.71	0.0001
G	3	243.23	81.08	23.36	0.0001
Y*Q	60	881.58	14.69	4.23	0.0001
Q*A	36	2711.01	75.31	21.70	0.0001
Q*G	9	341.64	37.96	10.94	0.0001
A*G	36	651.82	18.11	5.22	0.0001

North Atlantic 1956-75

Source	DF	Sum of Sq.s	Mean Sq.	F Value	Pr > F
Model	42	16064.87	382.50	100.49	0.0001
Error	3312	12606.53	3.81		
Corr. Tot.	3354	28671.40			

R-Sq.= 0.560 C.V.= -66.38

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	19	1341.69	70.62	18.55	0.0001
Q	3	953.07	317.69	83.46	0.0001
A	5	4866.20	973.24	255.69	0.0001
Q*A	15	915.47	61.03	16.03	0.0001

North Atlantic 1975-95

Source	DF	Sum of Sq.s	Mean Sq.	F Value	Pr > F
Model	155	32045.33	206.74	65.35	0.0001
Error	8164	25826.88	3.16		
Corr. Tot.	8319	57872.21			

R-Sq.= 0.554 C.V.= -38.53

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	20	337.63	16.88	5.34	0.0001
Q	3	141.03	47.01	14.86	0.0001
A	5	11423.06	2284.61	722.18	0.0001
G	3	37.33	12.44	3.93	0.0081
Y*A	100	1441.55	14.42	4.56	0.0001
Q*A	15	594.55	39.64	12.53	0.0001
Q*G	9	482.19	53.58	16.94	0.0001

South Atlantic 1956-75

Source	DF	Sum of Sq.s	Mean Sq.	F Value	Pr > F
Model	42	25011.07	595.50	167.30	0.0001
Error	3847	13693.45	3.56		
Corr. Tot.	3889	38704.52			

R-Sq.= 0.646 C.V.= -65.26

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	19	1805.40	95.02	26.69	0.0001
Q	3	578.75	192.92	54.20	0.0001
A	5	8504.53	1700.91	477.85	0.0001
Q*A	15	413.47	27.56	7.74	0.0001

South Atlantic 1975-95

Source	DF	Sum of Sq.s	Mean Sq.	F Value	Pr > F
Model	110	42405.45	385.50	107.99	0.0001
Error	12533	44739.71	3.57		
Corr. Tot.	12643	87145.16			

R-Sq.= 0.487 C.V.= -46.81

Source	DF	Type III SS	Mean Sq.	F Value	Pr > F
Y	20	882.98	44.15	12.37	0.0001
Q	3	272.45	90.82	25.44	0.0001
A	6	12354.72	2059.12	576.82	0.0001
G	3	834.24	278.08	77.90	0.0001
Y*Q	60	901.00	15.02	4.21	0.0001
Q*A	18	1550.95	86.16	24.14	0.0001

Table 3. Relative CPUE and the standardized CPUE which was adjusted to 1.0 in 1975, for each stock hypothesis, 1956-1995.

	Total Atlantic			North Atlantic			South Atlantic		
Year	Rel.CPUE	Rel.CPUE	Adj.CPUE	Rel.CPUE	Rel.CPUE	Adj.CPUE	Rel.CPUE	Rel.CPUE	Adj.CPUE
56	1.000		44.444	1.000		26.525	1.000		57.143
57	0.496		22.062	0.625		16.589	0.410		23.446
58	0.105		4.662	0.138		3.671	0.099		5.674
59	0.058		2.560	0.082		2.172	0.048		2.754
60	0.073		3.227	0.104		2.761	0.059		3.349
61	0.239		10.604	0.244		6.464	0.204		11.680
62	0.192		8.547	0.319		8.454	0.142		8.097
63	0.165		7.329	0.272		7.215	0.124		7.086
64	0.114		5.049	0.278		7.374	0.059		3.360
65	0.064		2.858	0.128		3.385	0.041		2.366
66	0.049		2.164	0.096		2.549	0.032		1.834
67	0.055		2.449	0.107		2.841	0.036		2.046
68	0.043		1.911	0.066		1.753	0.035		1.971
69	0.048		2.138	0.076		2.027	0.038		2.149
70	0.035		1.556	0.065		1.724	0.024		1.389
71	0.024		1.071	0.048		1.279	0.015		0.846
72	0.026		1.147	0.039		1.032	0.021		1.211
73	0.025		1.129	0.037		0.979	0.021		1.194
74	0.030		1.311	0.052		1.369	0.022		1.240
75	0.023	1.000	1.000	0.038	1.000	1.000	0.018	1.000	1.000
76		0.730	0.730		0.560	0.560		0.642	0.642
77		0.723	0.723		0.425	0.425		0.900	0.900
78		0.551	0.551		0.318	0.318		0.786	0.786
79		0.779	0.779		0.372	0.372		0.970	0.970
80		0.861	0.861		0.610	0.610		0.760	0.760
81		0.737	0.737		0.613	0.613		0.678	0.678
82		0.888	0.888		0.577	0.577		0.783	0.783
83		0.661	0.661		0.533	0.533		0.631	0.631
84		0.862	0.862		0.584	0.584		0.742	0.742
85		0.926	0.926		0.458	0.458		1.071	1.071
86		0.679	0.679		0.587	0.587		0.583	0.583
87		0.797	0.797		0.447	0.447		0.754	0.754
88		0.700	0.700		0.621	0.621		0.587	0.587
89		0.725	0.725		0.637	0.637		0.580	0.580
90		0.604	0.604		0.473	0.473		0.525	0.525
91		0.438	0.438		0.310	0.310		0.377	0.377
92		0.433	0.433		0.472	0.472		0.326	0.326
93		0.528	0.528		0.488	0.488		0.443	0.443
94		0.569	0.569		0.612	0.612		0.537	0.537
95		0.520	0.520		0.388	0.388		0.414	0.414

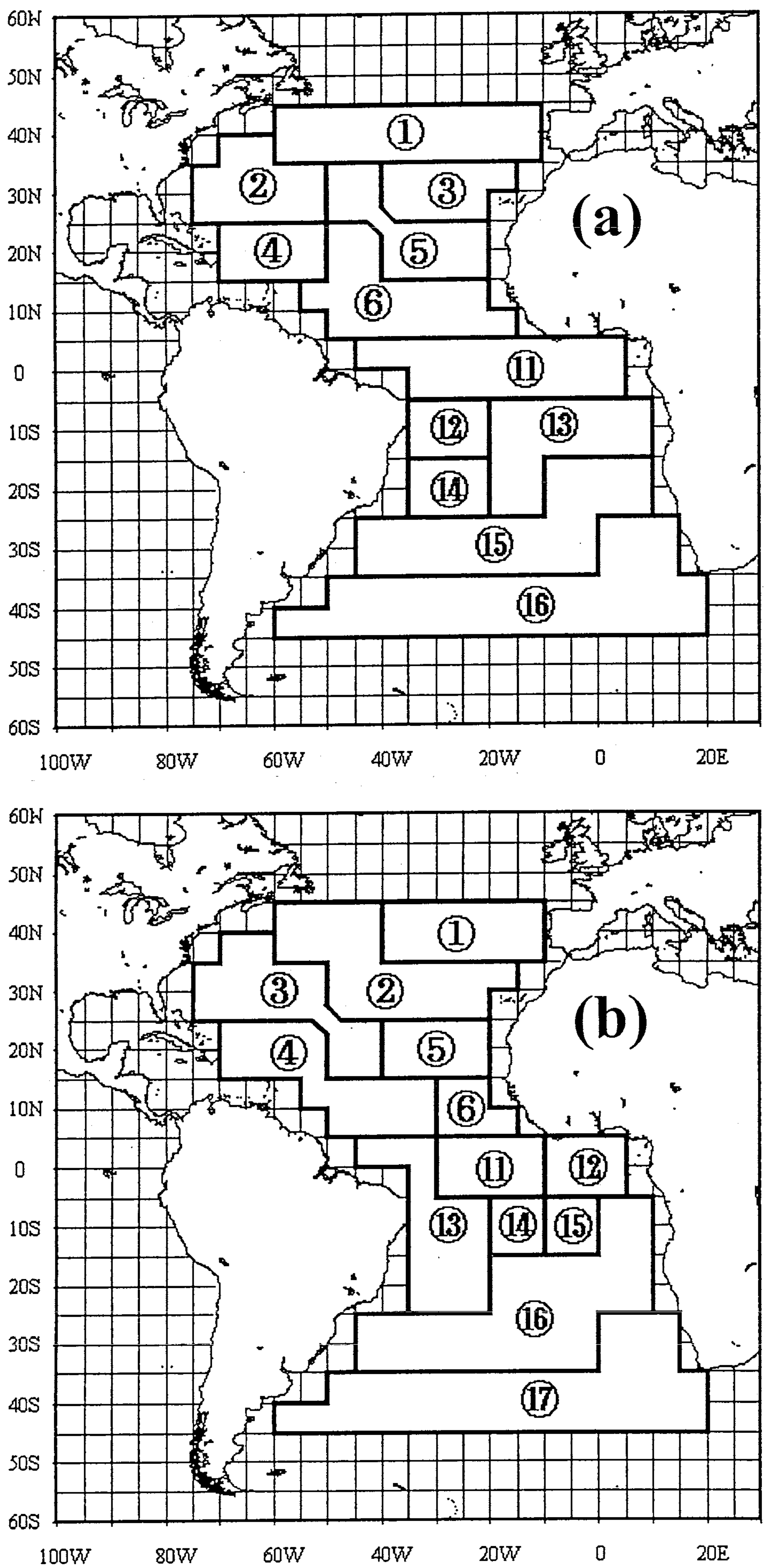

Figure 1. Subarea used in the standardization of CPUE for blue marlin. (a): period of 1956 to 1975; and (b): 1975 to 1995.

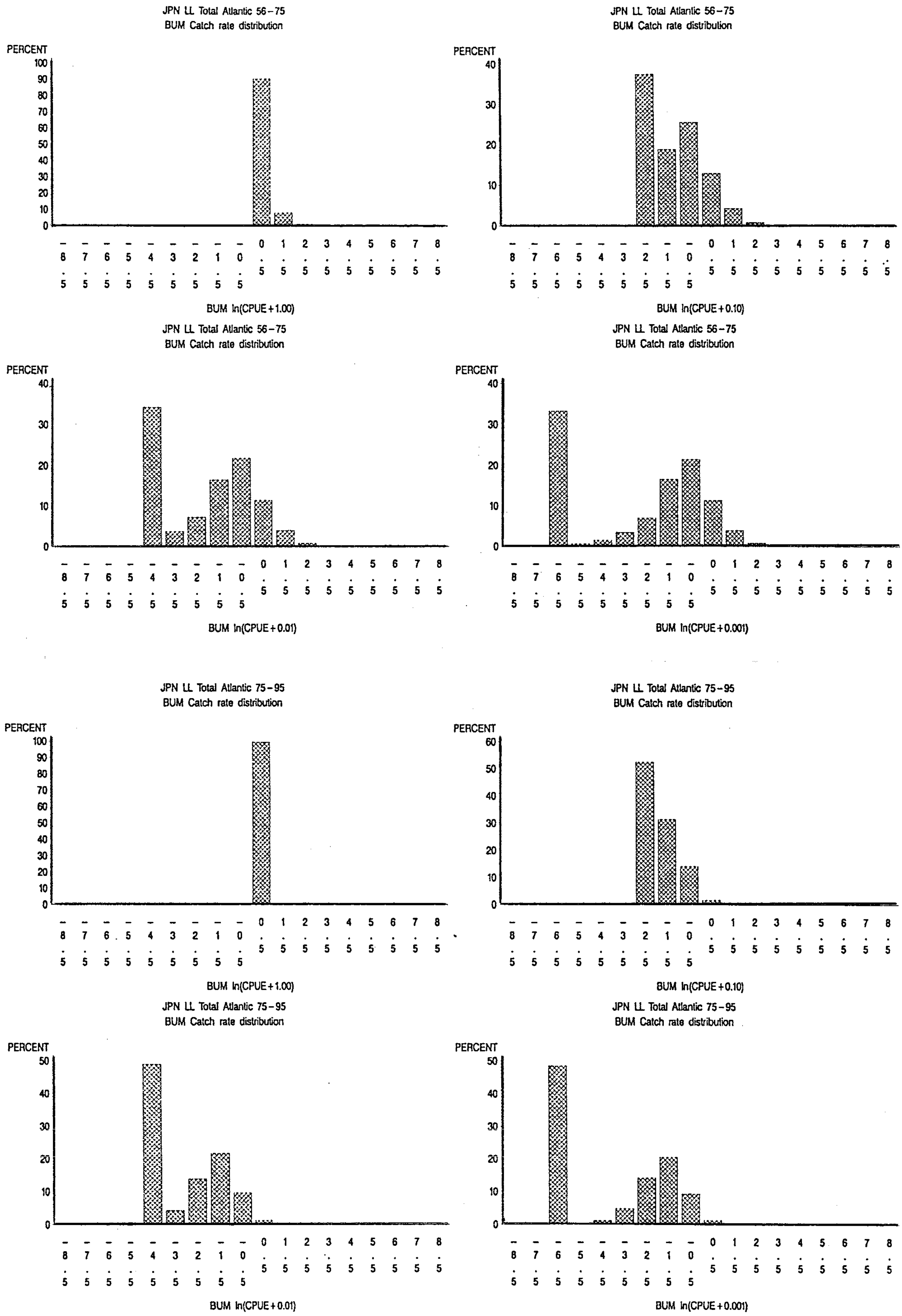

Figure 2. The distribution pattern of the log transformed CPUE of blue marlin with various constants in the total Atlantic for 1956-1975 (upper four) and for 1975-95 (lower four).

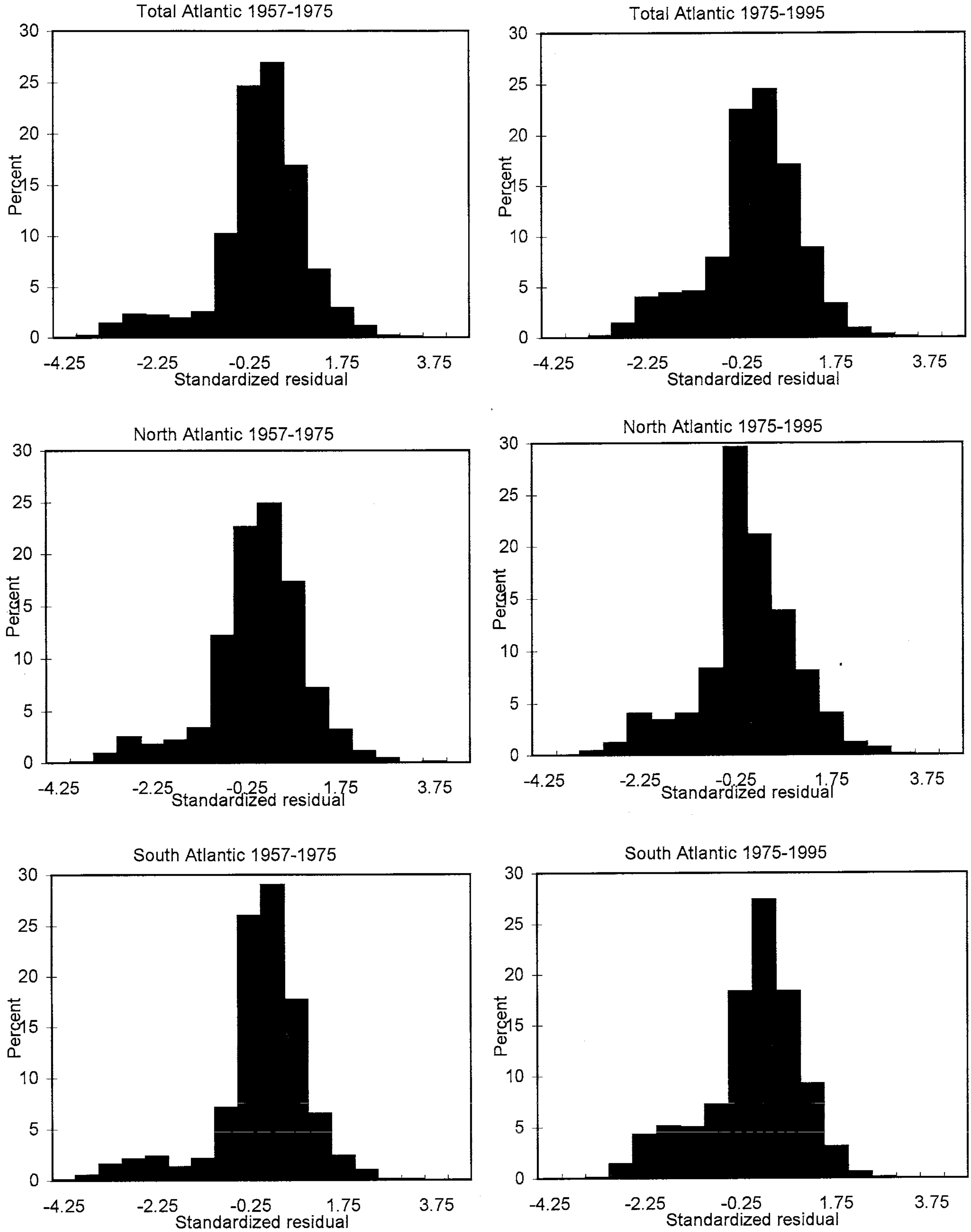

Figure 3. The distribution of standardized residuals of GLM in each period for each stock.

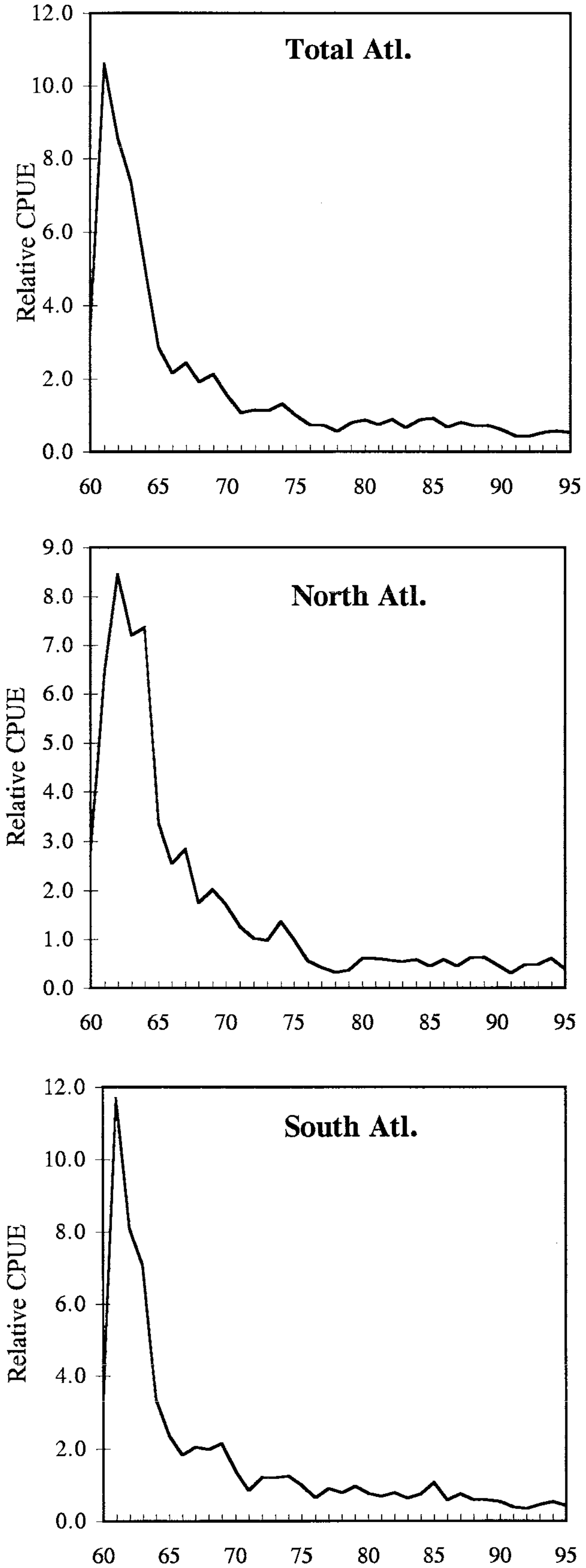

Figure 4A. Standardized CPUE of blue marlin, 1960-1995.
The 1975 value was adjusted to 1.0.

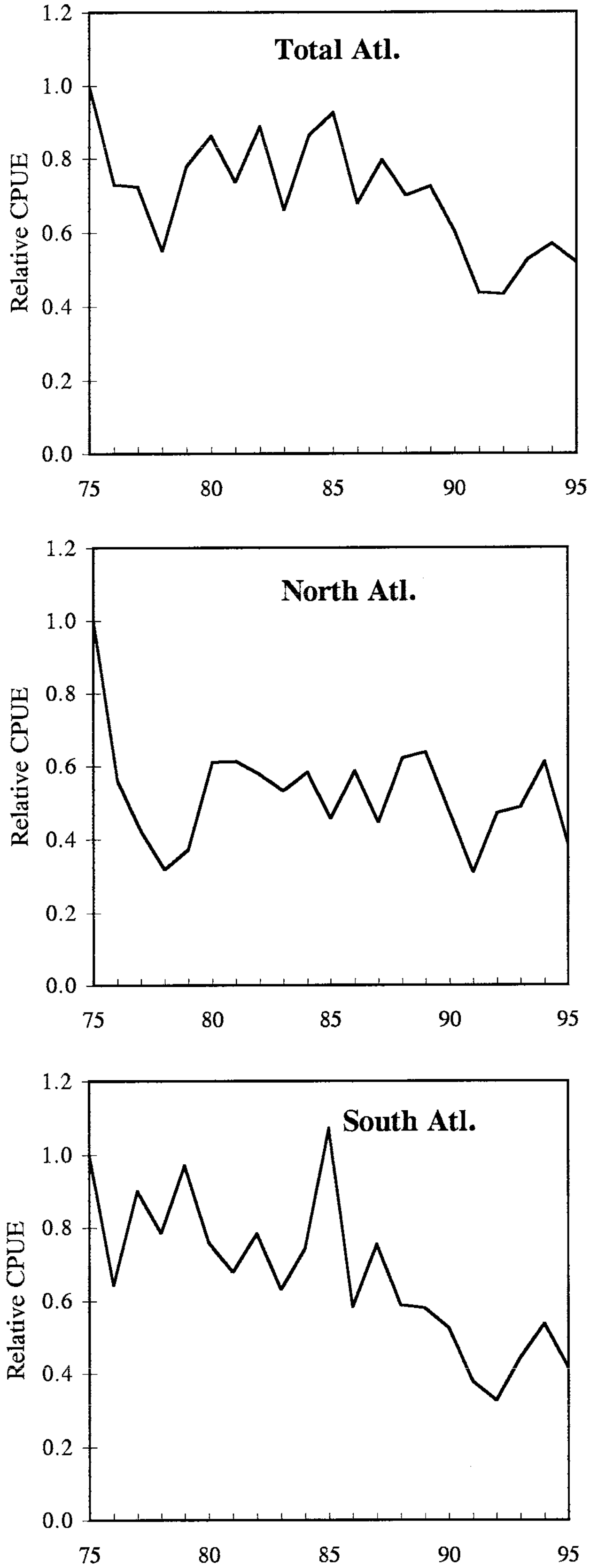

Figure 4B. Standardized CPUE of blue marlin, 1975-1995.
The 1975 value was adjusted to 1.0.