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THE HISTORICAL TREND OF STANDARDIZED CPUE FOR ALBACORE CAUGHT BY JAPANESE LONGLINE FISHERY IN THE ATLANTIC OCEAN

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ABSTRACT

The albacore CPUEs of the Japanese longline fishery are standardized by Generalized Linear Model (GLM) for north and south Atlantic. CPUEs in weight were used for the standardization. The data period from 1959 to 1992 were divided into the three periods, target, transition, and by-catch periods. In each period, the standardization of CPUEs was carried out. The CPUE in the north Atlantic continued to decrease through the three periods. In the south Atlantic the standardized CPUE decreased in the target and transition periods, but was stable in the by-catch period with some fluctuations.

RESUME

La CPUE germonière des palangriers japonais est standardisée par le modèle linéaire généralisé (GLM) pour l'Atlantique Nord et Sud. La standardisation utilisait des CPUE en poids. La période de données 1959-92 a été divisée en trois périodes, pêche dirigée, période de transition et pêche accessoire. La standardisation des CPUE a été effectuée pour chaque période. La CPUE nord-atlantique a baissé de façon continue pendant les trois périodes. Dans l'Atlantique Sud, la CPUE standardisée a diminué pendant les périodes de pêche dirigée et de transition, mais s'est montrée stable avec quelques fluctuations pendant la période de prise accessoire.

RESUMEN

Se hace una estandarización de las CPUEs del atún blanco de la pesquería palangrera japonesa, por medio del Modelo Lineal Generalizado (GLM), para el Atlántico norte y sur. En el proceso se usaron CPUEs en peso. Los datos de 1959 a 1992 se dividieron en tres períodos: objetivo, transición y captura fortuita. En cada uno de los períodos se llevó a cabo la estandarización de las CPUEs. La CPUE en el Atlántico norte se mantuvo en descenso durante los tres períodos. En el Atlántico sur, la CPUE estandarizada descendió durante los períodos de objetivo y transición, si bien permaneció estable en el período de captura fortuita con ciertas fluctuaciones.

1. INTRODUCTION

The Japanese longline fishery has a long history, initiated in 1956 in the western equatorial Atlantic Ocean. After the commencement of the operation, the Japanese longline fishery expanded its fishing ground rapidly and covered almost all tropical waters in the early 1960's. Since then, the longline vessels have shifted their operations towards the temperate waters due to the change in the economy, from securing export oriented canning materials such as yellowfin and albacore caught in the tropical waters to higher priced domestic sashimi materials such as southern bluefin and bigeye tunas in the temperate and tropical waters. According to the change of target species, the deep longline operations have been introduced in the tropical Atlantic Ocean since the late-1970's.

The catch of Atlantic albacore by Japanese longline fishery reached 30,000-43,000 tons in the 1960's, when the Japanese longline vessels targeted yellowfin and albacore, but the catch has continued to decrease sharply since then. In recent years, the albacore catch has amounted to around 1,000 tons. In the 1960's albacore was mainly caught in the tropical waters where the high *CPUE*s were observed, but in recent years it has been mainly caught as by-catch in the temperate waters.

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The Japanese longline fishery has changed during its long history as mentioned above, and the effect of the change of target species on *CPUE* is especially critical for monitoring the trend of stock abundance. The main fishing ground has been changed according to the change of target species. Furthermore, the deep longline operations were introduced in the late-1970's and the catchability of albacore probably changed. Therefore, in this study, *CPUEs* of the Japanese longline fishery were standardized using General Linear Model (GLM), taking into account the effects of the areas, time, gear configurations, and other species. Furthermore, the time periods were stratified into three periods, target, transition, and by-catch periods.

2. MATERIALS AND METHODS

2.1 Basic data

The basic data for this study were obtained from the Japanese longline fishery statistics compiled at the National Research Institute of Far Seas Fisheries (NRIFSF) for 1956-1992. Two kinds of databases were used. The Database-I is the same database which is submitted to ICCAT as the TASK-II. The Database-II contained sample statistics including additional information on gear configuration, i.e., the number of branch lines per basket (between floats), which is obtained from logbook records, but not raised to the total operations.

In these data bases, the catch is expressed in number. Using the catch at size of the Japanese albacore catch submitted to ICCAT, and length-weight relationship, the catch in weight was estimated to the corresponding catch in number. For the north Atlantic the length-weight relationship by Santiago (1993) was used and for the south Atlantic the relationship by Penney (1994) was used. The weight basis data were then constructed for Databases -I and II, respectively.

CPUE was calculated as catch (kg) per 1000 hooks. Observations with less than 3,000 hooks were excluded from the analysis. Database-I from 1959 to 1975 and Database-II from 1975 to 1992 were used in the present analysis, because Database-II has been collected since 1975.

Uozumi (1996) showed that there are three periods in the history of the Japanese longline fishery based on the historical changes in fishery strategy. Considering the historical changes in the fishery, the period from 1959 to 1992 was divided into three periods in this study; Target period from 1959 to 1969 when the *CPUE* fluctuated at a high level, Transition period from 1969 to 1975 when the nominal *CPUE* decreased sharply, and By-catch period from 1975 to 1992 when the *CPUE* was stable at a low level.

2.2 Selection of the model

Year, fishing season, fishing area, and *CPUEs* of other species were included as the main effects in the model in each period, and gear configuration was added as the main effect in the By-catch period. Quarter-of-the-year was selected as the fishing season. Based on the distribution of albacore *CPUEs* and the distribution of efforts, subareas were selected for the north and south Atlantic in each period as shown in Figure 1.

CPUEs of yellowfin, bigeye, and bluefin tunas were used as the species effect in the north Atlantic in the three periods. *CPUEs* of yellowfin and bigeye were used in the target period in the south Atlantic, then in addition to these species, the *CPUE* of southern bluefin tuna was used in the Transition and By-catch periods.

With regard to the gear configuration, 3 to 20 hooks between floats were observed in Database-II for the By-catch period from 1975 to 1992. These 18 levels were categorized to 4 levels (3-7, 8-11, 12-15, and 16-20 hooks between floats) arbitrarily.

The multiplicative model was selected. For Database-I in the Target and Transition periods, the model is:

$$\mathrm{LOG}(CPUE_{ijklmn}+1) = f\hat{E} + Y_i + Q_j + A_k + YFT_l + BET_m + BF_n + SBT_o + \text{Interactions} + e_{ijklmn}$$

For Database-II in the By-catch period, the model is:

$$\mathrm{LOG}(CPUE_{ijklmnop}+1) = f\hat{E} + Y_i + Q_j + A_k + YFT_l + BET_m + BF_n + SBT_o + G_p + \text{Interactions} + e_{ijklmop}$$

where LOG : natural logarithm,

$CPUE_{ijklmn}$	:	nominal *CPUE* (catch in number per 1000 hooks, in year *i*, quarter *j*, subarea *k* and effect of gear *l*),
*f*Ê	:	overall mean,
Y_i	:	effect of year *i*,
Q_j	:	effect of quarter *j*,
A_k	:	effect of subarea *k*,
YFT_l	:	effect of yellowfin *l*,
BET_m	:	effect of bigeye *m*,
BF_n	:	effect of bluefin *n*,
SBT_o	:	effect of southern bluefin *o*,
G_p	:	effect of gear *p*
Interactions	:	any combinations of two way interaction except for year term,
$e_{ijklmnop}$	:	error term.

Analysis was made through computer software, 'SAS Ver. 6.08.

3. RESULTS AND DISCUSSIONS

Various runs with any combinations of the two way interactions indicated that the estimates could be obtained with the model including significant interaction terms shown in Tables 1-6 for each period in the north and south Atlantic. Then the model composed of main effects and some interaction terms were selected for the three periods in the north and south Atlantic (Tables 1 -6).

The analyses of variance (Tables 1-6) revealed that all main effects and almost all of interactions were significant at 0.1% level for all periods in both the north and south Atlantic. The overall histograms of normalized residual from the final models were shown in Figures 2 and 3. The distribution of residuals in the six cases were not far from normal distributions, though there were some skewness. The rate of variability explained by the final model (i.e. R-Square) ranged from 0.73 in the north Atlantic Transition Period to 0.46 in the south Atlantic By-catch Period.

The standardized *CPUE*s were shown in Figures 2 and 3 with lower and upper 95% confidence limit. The *CPUE* in the north Atlantic (Figure 2) continued to decrease in all periods with some fluctuations. The *CPUE* decreased from 178 kg/1000 hooks in 1959 to 78 kg/ 1000 hooks in 1969 in the Target period. But this decrease occurred mainly in the earlier half of the period and the *CPUE* became relatively stable in the latter half. In the Transition period, the sharp decline was observed in the earlier four years and then became stable in the latter three years. The level of *CPUE* decreased from more than 50 kg/ 1000 hooks to less than 20 kg/ 1000 hooks in this period. In the By-catch period, the *CPUE* decreased sharply in the first five years from about 10 kg to 5 kg/ 1000 hooks and then continued to decrease gradually to about 2 kg/ 1000 hooks in 1992 with some fluctuations.

In the south Atlantic the *CPUE* decreased from 400 kg to 50 kg/1000 hooks in the Target period. Drastic decrease was observed in the earlier half of the period and became relatively stable in the latter half of the period. In the Transition period, the *CPUE* continued to decrease from 50 kg to 11 kg/ 1000 hooks. In the By-catch period, the *CPUE* has been relatively stable compared with the previous two periods. The *CPUE* fluctuated at about 8 kg/ 1000 hooks from 1975 to 1987 periodically. Then the level of *CPUE* decreased to around 5 kg/1000 hooks and has stabilized in the last five years.

The Japanese fishery has changed target species, fishing grounds, fishing gears, and so on, in its long history. In this paper, based on the history, the *CPUE* series were divided into three periods to eliminate possible bias during the standardization procedure, due to these drastic changes. In the Target and By-catch periods, the status of the fishery might be stable during each period, though the situations of the fishery were very different between these two periods. But in the Transition period, the change was so drastic that it may be questionable whether the GLM procedure could eliminate the biases.

The results of this paper should be confirmed by the analyses of the other major longline fisheries, especially Taiwanese fishery which have targeted albacore. In addition, age composition is very important information for the change of the stock status. Therefore, the analysis on the size and/or age composition of the longline fisheries is desirable for the assessment on the status of the recruitment into the longline fishery.

Table 1. Analysis of variance for North Atlantic Target Period from 1959-1969.
R-square=0.65, CV=28.5

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	84	8384.40	99.81	58.63	0.0001
Error	2661	4530.11	1.70		
Corrected Total	2745	12914.52			
Source	**DF**	**Sum of Square**	**Mean Square**	**F Value**	**Pr > F**
YR	10	128.20	12.82	7.53	0.0001
QT	3	284.85	94.95	55.77	0.0001
AREA	10	3881.61	388.16	228.01	0.0001
BF	4	41.59	10.40	6.11	0.0001
BET	3	62.79	20.93	12.29	0.0001
YFT	3	65.83	21.94	12.89	0.0001
QT*AREA	30	421.04	14.03	8.24	0.0001
QT*YFT	9	94.81	10.53	6.19	0.0001
BF*YFT	12	49.48	4.12	2.42	0.004

Table 2. Analysis of variance for North Atlantic Transition Period from 1969 to 1975.
R-square=0.73, CV=31.5

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	77	6946.54	90.21	68.47	0.0001
Error	1962	2585.05	1.32		
Corrected Total	2039	9531.59			
Source	**DF**	**Sum of Square**	**Mean Square**	**F Value**	**Pr > F**
YR	6	336.86	56.14	42.61	0.0001
QT	3	160.36	53.45	40.57	0.0001
AREA	10	2777.04	277.70	210.77	0.0001
BF	4	24.88	6.22	4.72	0.0009
BET	3	85.80	28.60	21.71	0.0001
YFT	3	74.96	24.99	18.96	0.0001
QT*AREA	30	243.43	8.11	6.16	0.0001
QT*YFT	9	62.24	6.92	5.25	0.0001
BET*YFT	9	63.05	7.01	5.32	0.0001

Table 3. Analysis of variance for North Atlantic Bycatch Period from 1975 to 1992.
R-square=0.53, CV=67.4

Source	DF	Sum of Square	Mean Square	F Value	Pr > F
Model	92	16712.06	181.65	112.71	0.0001
Error	9042	14572.69	1.61		
Corrected Total	9134	31284.75			
Source	**DF**	**Sum of Square**	**Mean Square**	**F Value**	**Pr > F**
YR	17	687.43	40.44	25.09	0.0001
QT	3	765.32	255.11	158.29	0.0001
AREA	8	7020.58	877.57	544.51	0.0001
GEAR	3	50.44	16.81	10.43	0.0001
BF	4	100.74	25.18	15.63	0.0001
BET	3	340.74	113.58	70.47	0.0001
YFT	3	378.33	126.11	78.25	0.0001
QT*AREA	24	627.21	26.13	16.22	0.0001
QT*YFT	9	84.55	9.39	5.83	0.0001
BET*YFT	9	106.27	11.81	7.33	0.0001
QT*BET	9	52.26	5.81	3.60	0.0002

Table 4. **Analysis of variance for South Atlantic Target Period from 1959-1969.**
R-square=0.58, CV=28.0

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	74	8112.22	109.62	57.71	0.0001
Error	3086	5861.84	1.90		
Corrected Total	3160	13974.05			
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
YR	10	670.23	67.02	35.28	0.0001
QT	3	56.93	18.98	9.99	0.0001
AREA	6	1413.52	235.59	124.03	0.0001
BET	3	179.48	59.83	31.50	0.0001
YFT	3	364.13	121.38	63.90	0.0001
SBT	4	47.65	11.91	6.27	0.0001
QT*AREA	18	1010.61	56.14	29.56	0.0001
QT*YFT	9	89.86	9.98	5.26	0.0001
QT*BET	9	69.06	7.67	4.04	0.0001
BET*YFT	9	137.97	15.33	8.07	0.0001

Table 5. **Analysis of variance for South Atlantic Transition Period from 1969 to 1975.**
R-square=0.67, CV=41.4

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	80	6368.65	79.61	42.68	0.0001
Error	1668	3111.11	1.87		
Corrected Total	1748	9479.76			
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
YR	6	250.63	41.77	22.40	0.0001
QT	3	275.54	91.85	49.24	0.0001
AREA	7	1294.25	184.89	99.13	0.0001
BET	3	294.09	98.03	52.56	0.0001
YFT	3	46.02	15.34	8.22	0.0001
SBT	4	101.34	25.34	13.58	0.0001
QT*AREA	21	335.62	15.98	8.57	0.0001
QT*SBT	12	23.82	1.98	1.06	0.3867
BET*YFT	9	40.90	4.54	2.44	0.0094
BET*SBT	12	315.42	26.28	14.09	0.0001

Table 6. **Analysis of variance for South Atlantic Bycatch Period from 1975 to 1992.**
R-square=0.46, CV=95.2

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	95	13374.58	140.79	93.41	0.0001
Error	10471	15780.91	1.51		
Corrected Total	10566	29155.49			
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
YR	17	431.51	25.38	16.84	0.0001
QT	3	214.09	71.36	47.35	0.0001
AREA	8	6587.15	823.39	546.34	0.0001
GEAR	3	212.66	70.89	47.03	0.0001
BET	3	1398.87	466.29	309.39	0.0001
YFT	3	271.50	90.50	60.05	0.0001
SBT	4	57.92	14.48	9.61	0.0001
QT*BET	9	45.16	5.02	3.33	0.0005
QT*AREA	24	661.57	27.57	18.29	0.0001
QT*SBT	12	38.53	3.21	2.13	0.0124
BET*YFT	9	44.63	4.96	3.29	0.0005

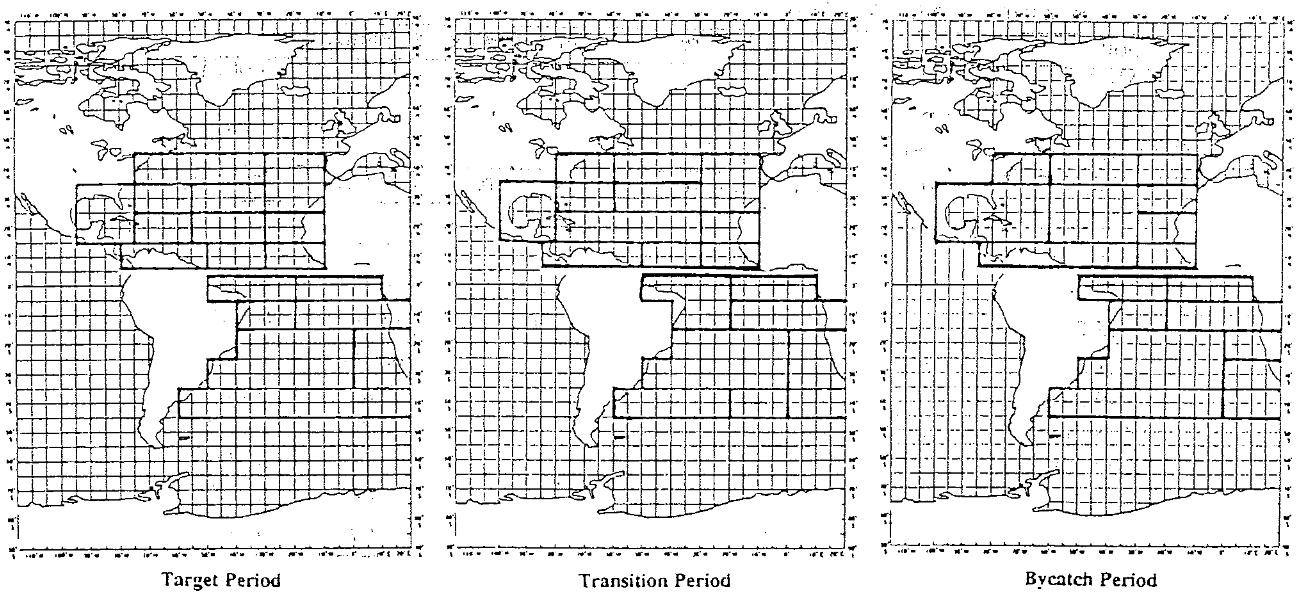

Fig. 1. Subareas used for GLM analysis for 1959-1969, 1969-1975 and 1975-1992 periods.

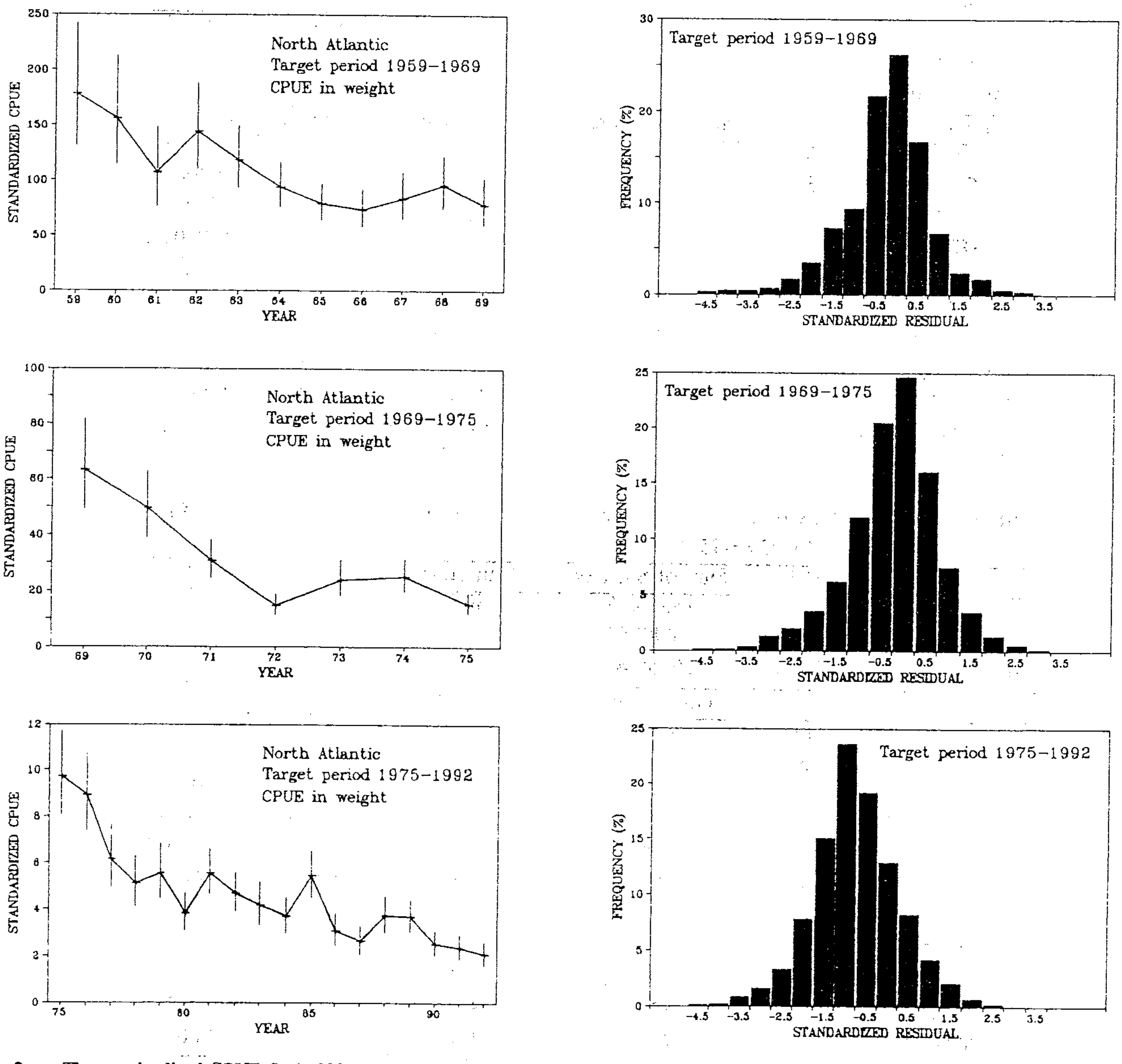

Fig. 2. The standardized CPUE (kg/ 1000 hooks) for each period in the north Atlantic. Right panels show overall histograms of normalized residuals from the final model.

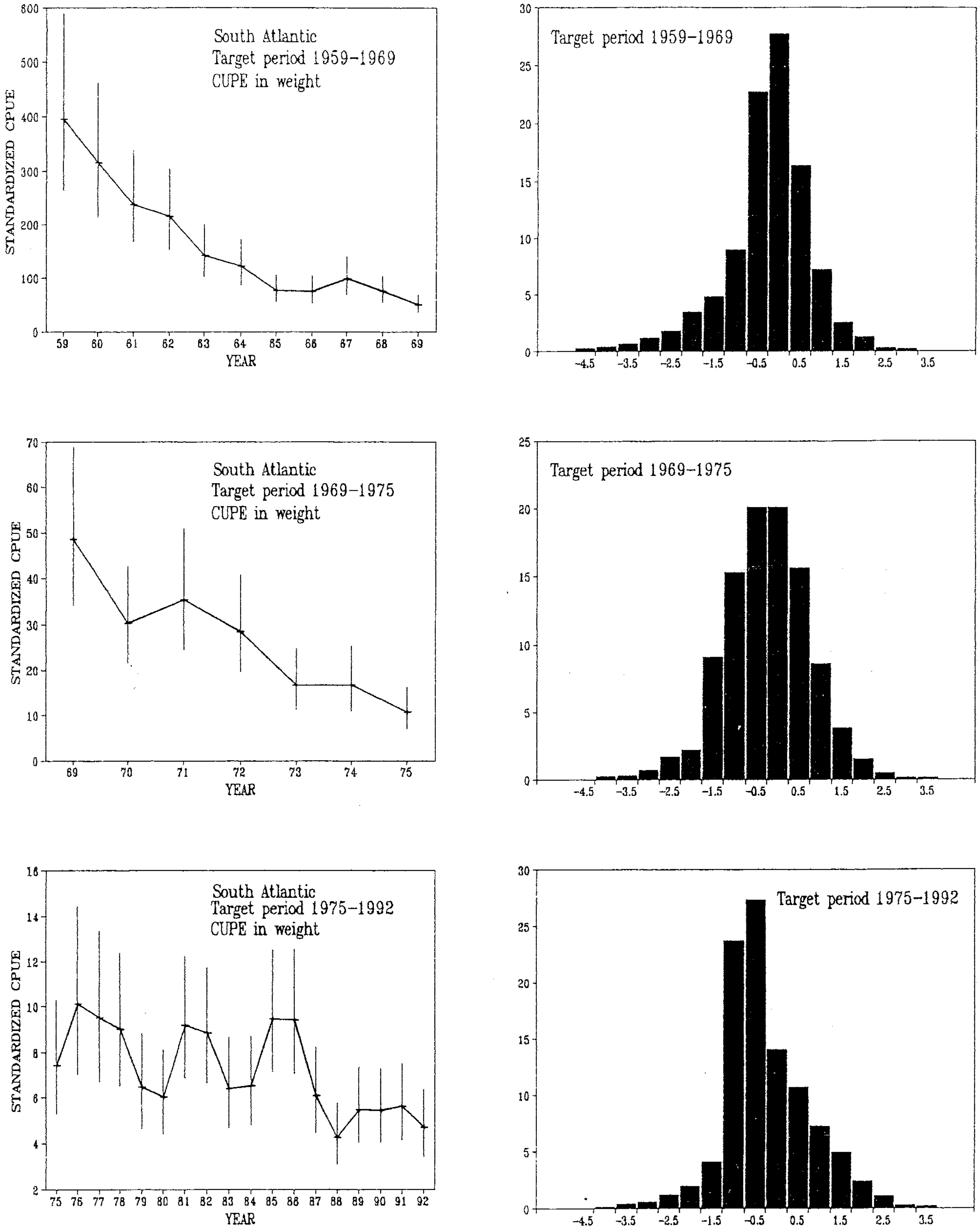

Fig. 3. The standardized CPUE (kg/ 1000 hooks) for each period in the south Atlantic. Right panels show overall histograms of normalized residuals from the final model.