STANDARDIZED JAPANESE LONGLINE CPUE FOR BIGEYE TUNA IN THE INDIAN OCEAN UP TO 2001

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ABSTRACT

Japanese longline CPUE for bigeye tuna from 1960 to 2001 was standardized by GLM. Since SST (Sea Surface Temperature) and SOI (Southern Oscillation Index) were applied as environmental factors in a previous study, MLD (Mixed Layer Depth) was tested to apply instead of SOI. As a result of GLM analyses, CPUE standardization including MLD and SST in the model seems to be more reliable than that including SOI and SST although the trends of standardized CPUE derived from these two Models were quite similar. In the Tropical Area, the main longline fishing ground for bigeye, the CPUE has continuously declined since 1987. Although the decline from 1987 to 1993 seems to be in the range of fluctuation observed in the past three decades, that after 1993 is the lowest level for Japanese longline history in the Indian Ocean.

1. INTRODUCTION

In 2001, bigeye CPUE of Japanese longline fishery was standardized for the period from 1952 to 1999 using GLM method in which the SST (Sea Surface Temperature) and SOI (Southern Oscillation Index) were applied (Okamoto et al. 2001). However, as SOI is the index in the Pacific Ocean, it is vague if it is appropriate for use in the Indian Ocean. Furthermore, even if SOI indicates the similar oceanographic event in Indian Ocean, SOI can never explain the actual time-area changes in the local environment because the effect of change in SOI trend does not appear at all area at the same time and at the same level. In general, change in SOI trend causes the change in the SST (Sea Surface Temperature) and MLD especially at the equatorial region in the Pacific Ocean (Glantz 1998). Then actual MLD and SST (and MLD-SST interaction) data in Indian Ocean were applied to the GLM analysis as the environmental factors instead of SOI, and bigeye CPUE of Japanese longline fishery was standardized from 1960 up to 2001.

2. MATERIALS AND METHODS

AREA DEFINITION:

Area definition used in this study was the same as the area revised in Okamoto et al. (2001) as shown in Fig. 1. Main fishing ground of Japanese longline fishery was divided into seven sub-areas and CPUE standardization was done for three cases of the sub-area combinations, Tropical (sub-areas 1-5), South (sub-areas 6&7) and ALL (sub-areas 1-7) Indian Ocean.

ENVIRONMENTAL FACTORS:

As environmental factors, which are available for the analyzed period from 1960 to 2001, SST (Sea Surface Temperature), SOI (Southern Oscillation Index) and MLD (Mixed Layer Depth) were applied.

1) SST

The original SST data whose resolution is 2-degree latitude and 2-degree longitude by month from 1946 to 2002, was downloaded from NEAR-GOOS Regional Real Time Data Base of Japan Meteorological Agency (JMA).

http://goos.kishou.go.jp/rrtdb/database.html

It is necessary to get password to access the data retrieving system. The original data was recompiled into 5-degree latitude and 5-latitude longitude by month from 1960 to 2001, and used in the analyses.

2) SOI

Monthly SOI data used was taken from NOAA (National Oceanic & Atmospheric Administration) and was downloaded from the following site.

ftp://ftp.ncep.noaa.gov/pub/cpc/wd52dg/data/indices/soi

3) MLD

MLD data from 1960 to 2002 was downloaded from JEDAC (Joint Environmental Data Analysis Center) website of Scripps Institution of Oceanography.

http://jedac.ucsd.edu/DATA_IMAGES/index.html

The Original MLD data, which the resolution is 2-degree latitude and 5-degree longitude (corner of grid) by month, was recompiled to 5-degree latitude and 5-degree longitude (center of grid) by month. In the case there were strata in which MLD data was not exist in spite of that the longline operations were made in the strata, appropriate substitution of MLD data was made to fill the strata.

CATCH AND EFFORT DATA USED:

The Japanese longline catch (in number) and effort statistics from 1960 up to 2001 were used. 2001 data is preliminary. The catch and effort data set from aggregated by month, 5-degree square and the number of hooks between floats (NHF), was used for the analysis. Data in strata in which the number of hooks was less than 10000 were not used for analyses. As the NHF information does not available for the period from 1960 to 1974, NHF was regarded to be 5 in this period.

GLM (GENERAL LINEAR MODEL):

CPUEs based on the number of catch was used.

The number of caught fish / the number of hooks * 1000

Two models were used for GLM analyses (log normal error structure model), model with SST and SOI and that with SST and MLD as environmental factors respectively.

Model_old (with SST and SOI):

$$\text{Log}(CPUE_{ijkl}+const)=\mu+YR_{(i)}+MN_{(j)}+AREA_{(k)}+NHF_{(l)}+SST(m)+SOI(n)+YR(i)*AREA_{(k)}+MN(j)*AREA_{(k)}+AREA(k)*NHFCL(l)+AREA(k)*SST(m)+AREA(k)*SOI(n)+e_{(ijkl....)}$$

Model_new (with SST and MLD):

$$\text{Log}(CPUE_{ijkl}+const)=\mu+YR_{(i)}+MN_{(j)}+AREA_{(k)}+NHF_{(l)}+SST(m)+MLD(n)+YR(i)*AREA_{(k)}+MN(j)*AREA_{(k)}+AREA(k)*NHFCL(l)+AREA(k)*SST(m)+AREA(k)*MLD(n)+SST(k)*MLD(n)+e_{(ijkl....)}$$

Where Log : natural logarithm,

CPUE: catch in number of bigeye per 1000 hooks,

Const: 10% of overall mean of CPUE

μ: overall mean,

$YR_{(i)}$: effect of year,

$MN_{(j)}$: effect of fishing season (month),

$AREA_{(k)}$: effect of sub-area,

$NHFCL_{(l)}$: effect of gear type (class of the number of hooks between floats),

$SST_{(m)}$: effect of SST,

$SOI_{(n)}$: effect of SOI,

$MLD_{(n)}$: effect of MLD,

YR (i)*AREA (k): interaction term between year and sub-area,

MN (j)*AREA (k): interaction term between fishing season and sub-area,

AREA (k)*NHFCL (l): interaction term between sub-area and gear type,

AREA(k)*SST (m): interaction term between sub-area and SST,

AREA(k)*SOI(n): interaction term between sub-area and SOI,

AREA(k)*MLD(n): interaction term between sub-area and MLD,

SST(m)*MLD(n): interaction term between SST and MLD,

$e_{(ijkl..)}$: error term.

The number of hooks between float (NHF) were divided into 3 classes (NHFCL 1: 5-9, NHFCL 2: 10-15, NHFCL 3: 16-21).

Effect of each Year was gotten by the method used in Ogura and Shono (1999) that uses lsmean of Year-Area interaction as the following equation.

$$CPUE_i = \Sigma\, W_j * (\exp(\text{lsmean}(\text{Year } i*\text{Area }_j))-\text{constant})$$

Where $CPUE_i$ = CPUE in year i,

W_j = Area rate of Area j , ($\Sigma W_j = 1$),

$\text{lsmean}(\text{Year*Area}_{ij})$ = least square mean of Year-Area interaction in Year i

and Area j,

constant = 10% of overall mean of CPUE.

3. RESULTS AND DISCUSSION

RELATIONSHIP BETWEEN MLD AND CPUE:

Geographic distribution of MLD averaged by quarter from 1991 to 2000 was shown in Fig. 2. The MLD data shown in the figure was recompiled from original data to the strata of this study (5 x 5 degree by month), and substitution was not made. There is no MLD data throughout the study years in the large area West and South of Madagascar to Cape Town and South of 35ºS, which consists of most part of sub-area 6 and south part of sub-area 7. Although the missing MLD data in these strata was also substituted to use for CPUE standardization, the data in these sub-areas may not be reliable.

Relationships between MLD and L-CPUE (log (CPUE+0.1)) for Tropical area was plotted in Fig. 3 in different color for each sub-area with regression line for each sub-area (in the same color as that for sub-area) and that (black solid line) for all tropical area (sub-area 1-5).

Positive relationships were observed in the 1st, 3rd and 4th quarters while negative relationship was slightly observed in the 2nd quarter. Since this simple observation of the relationship between MLD and CPUE was done in this study, the further analyses are desirable to grasp their relationship including SST.

CPUE STANDARDIZATIONS BY GLM:

The bigeye CPUE (catch in number per 1000 hooks) was standardized by GLM using each of two models described in the materials and method section. Results of ANOVA and distributions of the standard residual in each analysis were shown in Table 1 and Fig. 4, respectively. In all analyses, distributions of the standard residual did not show remarkable difference from the normal distribution. As far as judging from R-square, new model showed better fit than old model in all area categories although the difference is small. In the old model, effects of SOI and AREA*SOI were not significant for South Area while that of MLD, AREA*MLD and SST*MLD were significant for all area categories except for that of Area*MLD in South Area. As a result, CPUE standardization including MLD and SST in the model seems to be more reliable than that including SOI and SST.

Trends of relative CPUE standardized by both models in each area category (Tropical, South and All Indian Ocean) were shown in Fig. 5. The CPUEs derived from two models showed quite similar trend in each of three area categories. In the Tropical Area, the main longline fishing ground for bigeye, the CPUE has continuously declined since 1987. Although the decline from 1987 to 1993 seems to be in the range of fluctuation observed in the past three decades, that after 1993 is in the historically lowest level. In the South Area, the relative CPUE fluctuated drastically, and no clear trend was observed. Considering that the South Area is not major fishing ground for bigeye, and that real scaled CPUE in this area is less than half of that in the Tropical Area (Fig. 6), it would be better to refer the CPUE in the Tropical Area to grasp the abundance trend of this species. Even if the CPUE estimated for all Indian Ocean (sub-area 1-7) is reffered that after 1997 is the lowest level in the Japanese longline history in this Ocean.

4. RECERENCES

GLANTZ, M. (1998): Elniño (translated to Japanese by Y. Kaneko from “Currents of change” published in 1996). Dainippon insatsu co., Japan, 281pp.

OKAMOTO, H., N. MIYABE AND T. MATSUMOTO (1998): GLM analyses for Japanese longline CPUE for bigeye in the Indian Ocean applying environmental factors. IOTC/TTWP-01-21, 38pp.

Table 1:

	Model old							Model new						
	Source	D.F.	S.S.	M.S.	F Value	Pr > F	R-Square	Source	D.F.	S.S.	M.S.	F Value	Pr > F	R-Square
	Model	284	2670.588	9.403	27.87	<.0001	0.323444	Model	285	2717.67	9.54	28.51	<.0001	0.329147
	Year	41	555.41	13.55	40.16	<.0001		Year	41	587.30	14.32	42.82	<.0001	
	Month	11	146.63	13.33	39.52	<.0001		Month	11	124.50	11.32	33.83	<.0001	
	Area	4	67.81	16.95	50.26	<.0001		Area	4	59.64	14.91	44.57	<.0001	
	NHFCL	2	119.51	59.76	177.14	<.0001		NHFCL	2	113.83	56.92	170.14	<.0001	
TROPICAL	SST	1	135.41	135.41	401.40	<.0001		SST	1	19.51	19.51	58.32	<.0001	
	SOI	1	2.55	2.55	7.55	0.006		MLD	1	3.46	3.46	10.33	0.0013	
	Year*Area	164	476.21	2.90	8.61	<.0001		Year*Area	164	475.67	2.90	8.67	<.0001	
	Month*Area	44	168.26	3.82	11.34	<.0001		Month*Area	44	166.72	3.79	11.33	<.0001	
	Area*NHFCL	8	80.09	10.01	29.68	<.0001		Area*NHFCL	8	72.80	9.10	27.20	<.0001	
	Area*SST	4	68.84	17.21	51.02	<.0001		Area*SST	4	63.10	15.77	47.16	<.0001	
	Area*SOI	4	7.64	1.91	5.66	0.0002		Area*MLD	4	13.82	3.46	10.33	<.0001	
								SST*MLD	1	4.82	4.82	14.40	0.0001	
	Model	113	5396.31	47.75	60.90	<.0001	0.347943	Model	114	6348.96	55.69	78.40	<.0001	0.409368
	Year	41	615.15	15.00	19.13	<.0001		Year	41	528.74	12.90	18.15	<.0001	
	Month	11	926.46	84.22	107.40	<.0001		Month	11	622.84	56.62	79.71	<.0001	
	Area	1	779.83	779.83	994.45	<.0001		Area	1	160.32	160.32	225.68	<.0001	
	NHFCL	2	52.65	26.32	33.57	<.0001		NHFCL	2	41.50	20.75	29.21	<.0001	
SOUTH	SST	1	543.51	543.51	693.09	<.0001		SST	1	141.28	141.28	198.88	<.0001	
	SOI	1	1.86	1.86	2.38	0.1232		MLD	1	537.80	537.80	757.07	<.0001	
	Year*Area	41	239.25	5.84	7.44	<.0001		Year*Area	41	204.71	4.99	7.03	<.0001	
	Month*Area	11	448.31	40.76	51.97	<.0001		Month*Area	11	329.06	29.91	42.11	<.0001	
	Area*NHFCL	2	10.92	5.46	6.96	0.0009		Area*NHFCL	2	11.33	5.66	7.97	0.0003	
	Area*SST	1	990.87	990.87	1263.56	<.0001		Area*SST	1	248.04	248.04	349.17	<.0001	
	Area*SOI	1	0.58	0.58	0.74	0.3902		Area*MLD	1	0.09	0.09	0.13	0.718	
								SST*MLD	1	415.95	415.95	585.54	<.0001	
	Model	398	12019.93	30.20	62.74	<.0001	0.458792	Model	399	12785.89	32.04	70.37	<.0001	0.488028
	Year	41	635.08	15.49	32.18	<.0001		Year	41	676.26	16.49	36.22	<.0001	
	Month	11	211.93	19.27	40.02	<.0001		Month	11	122.99	11.18	24.55	<.0001	
	Area	6	635.74	105.96	220.11	<.0001		Area	6	219.68	36.61	80.40	<.0001	
	NHFCL	2	163.38	81.69	169.7	<.0001		NHFCL	2	150.65	75.33	165.41	<.0001	
ALL_IND	SST	1	197.97	197.97	411.25	<.0001		SST	1	14.15	14.15	31.07	<.0001	
	SOI	1	4.10	4.10	8.51	0.0035		MLD	1	280.19	280.19	615.27	<.0001	
	Year*Area	246	1162.85	4.73	9.82	<.0001		Year*Area	246	1106.48	4.50	9.88	<.0001	
	Month*Area	66	1038.42	15.73	32.68	<.0001		Month*Area	66	795.01	12.05	26.45	<.0001	
	Area*NHFCL	12	141.41	11.78	24.48	<.0001		Area*NHFCL	12	134.14	11.18	24.55	<.0001	
	Area*SST	6	799.82	133.30	276.92	<.0001		Area*SST	6	359.24	59.87	131.48	<.0001	
	Area*SOI	6	9.02	1.50	3.12	0.0047		Area*MLD	6	53.70	8.95	19.65	<.0001	
								SST*MLD	1	317.03	317.03	696.16	<.0001	

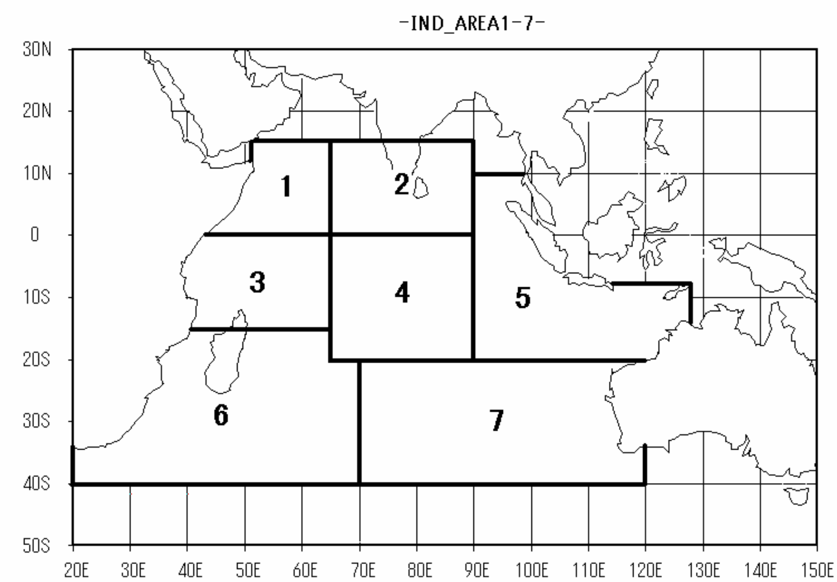

Fig. 1 Definition of sub-areas used in this study. TROPICAL, SOUTH and ALL INDIAN area categories in this paper consist of sub-areas 1-5, sub-areas 6-7 and sub-areas1-7, respectively.

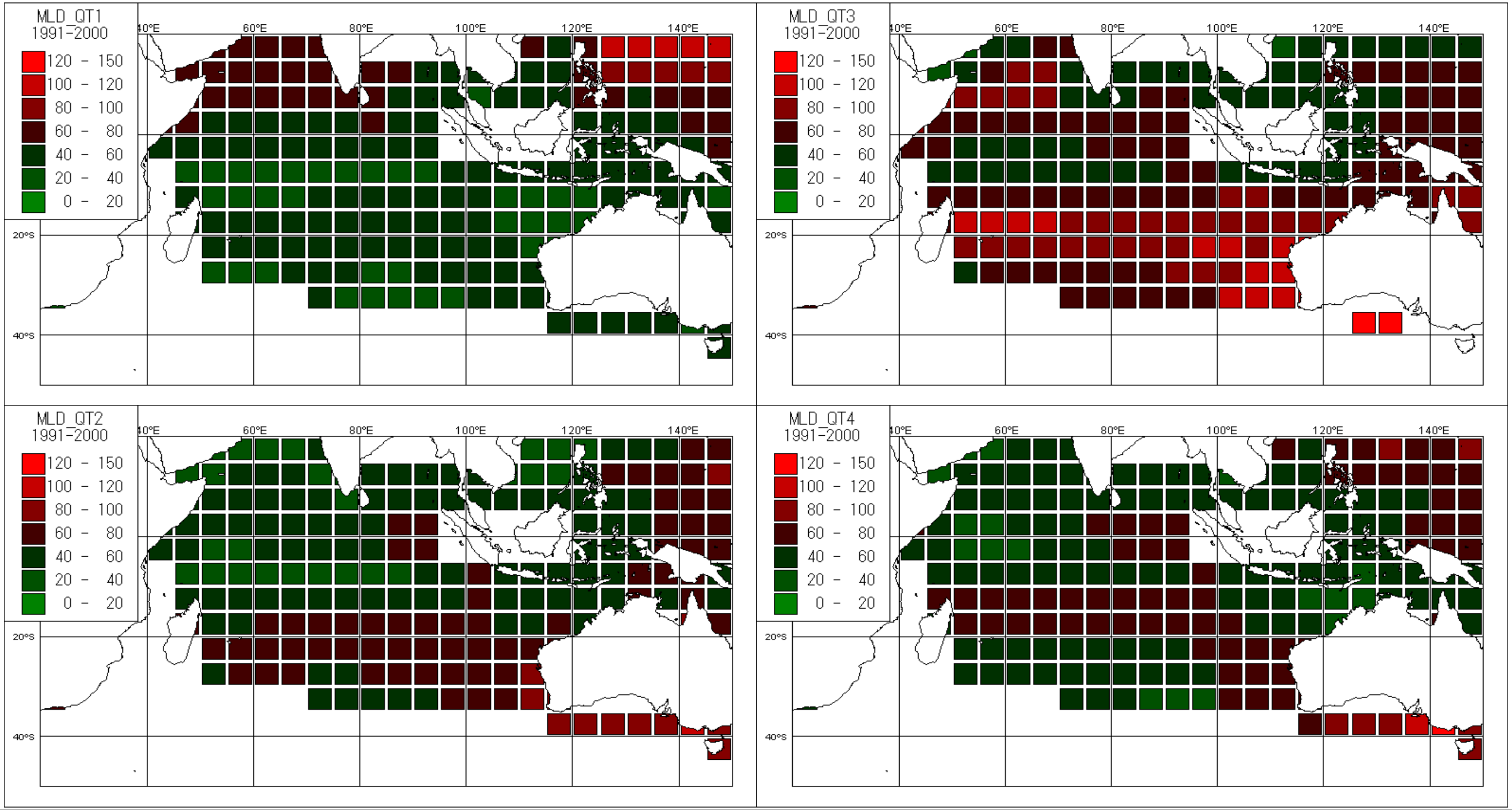

Fig. 2 Geographical distributions of MLD in quarter averaged from 1991 through 2000.

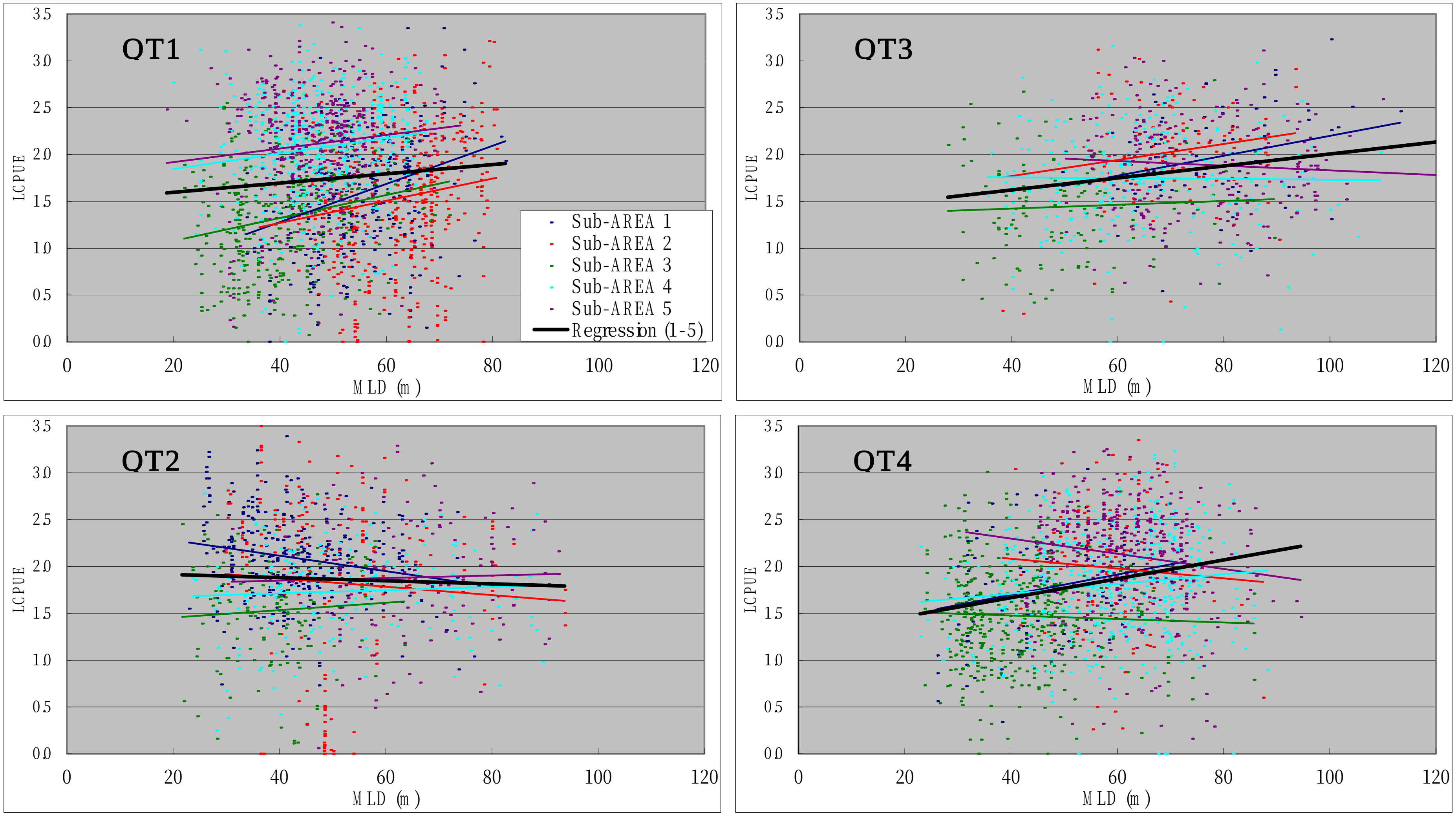

Fig. 3 Relationships between MLD and logarithmic CPUE (= log (CPUE + 0.1)) in each quarter using data from 1991 to 2001.

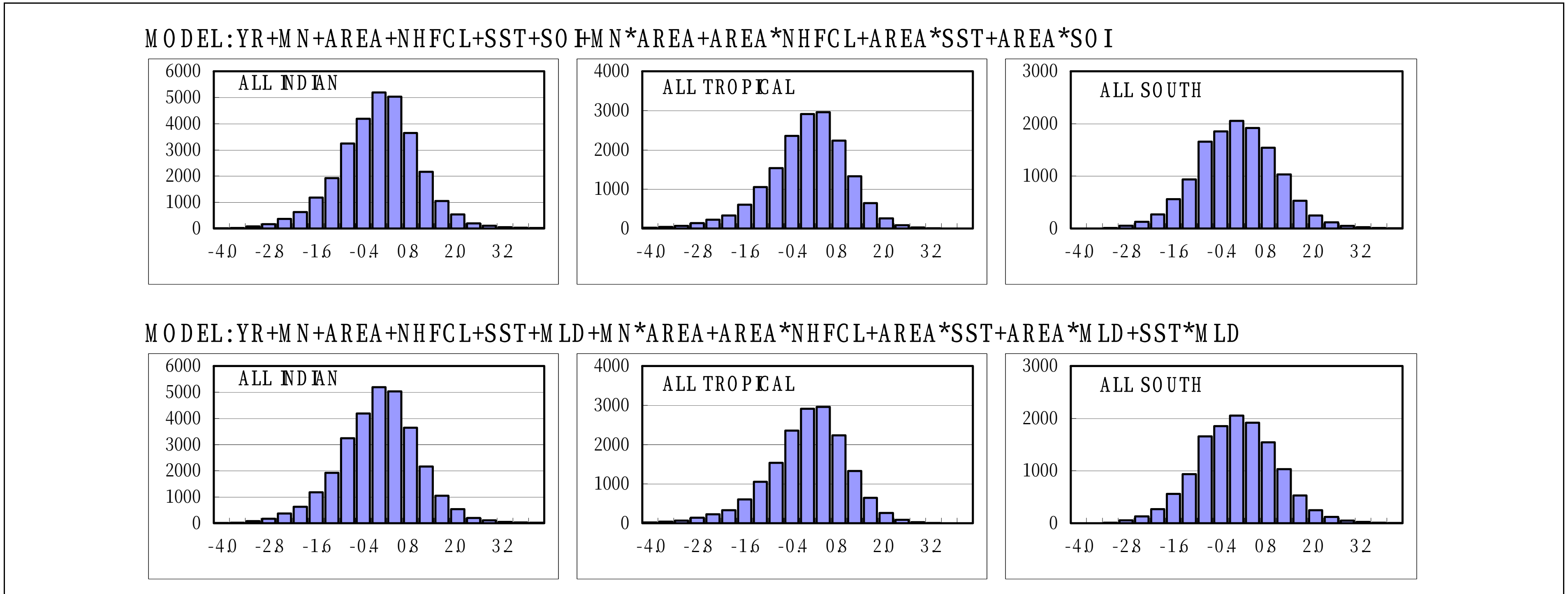

Fig. 4 Overall histograms of standard residuals from GLM using two types of model for three area categories.

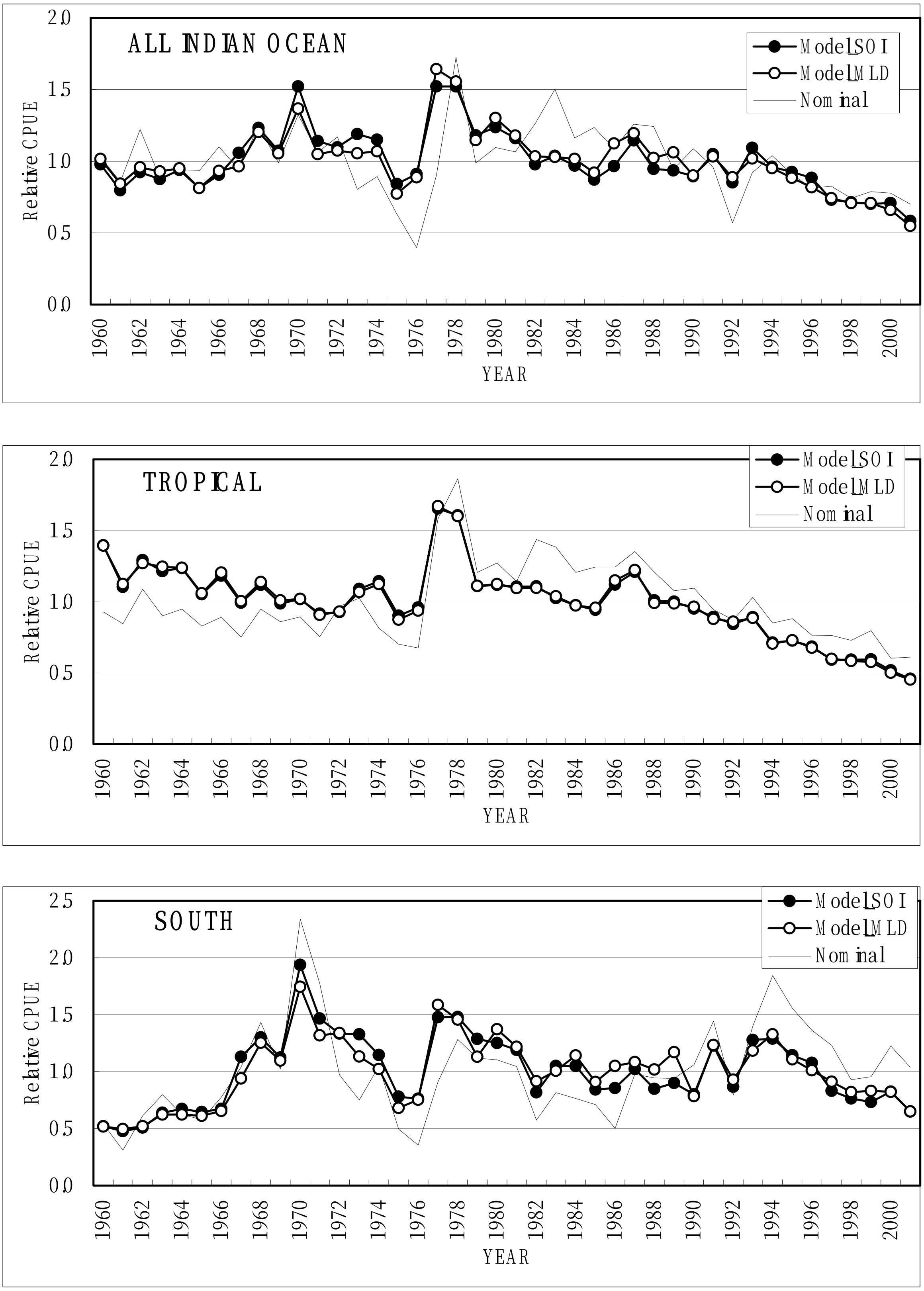

Fig. 5 Relative CPUEs for all Indian, Tropical and South areas derived from two models.

Model_SOI: YR+MN+AREA+NHFCL+SST+SOI+MN*AREA+AREA*NHFCL+AREA*SST+AREA*SOI

Model_MLD:
YR+MN+AREA+NHFCL+SST+MLD+MN*AREA+AREA*NHFCL+AREA*SST+AREA*MLD+ SST*MLD

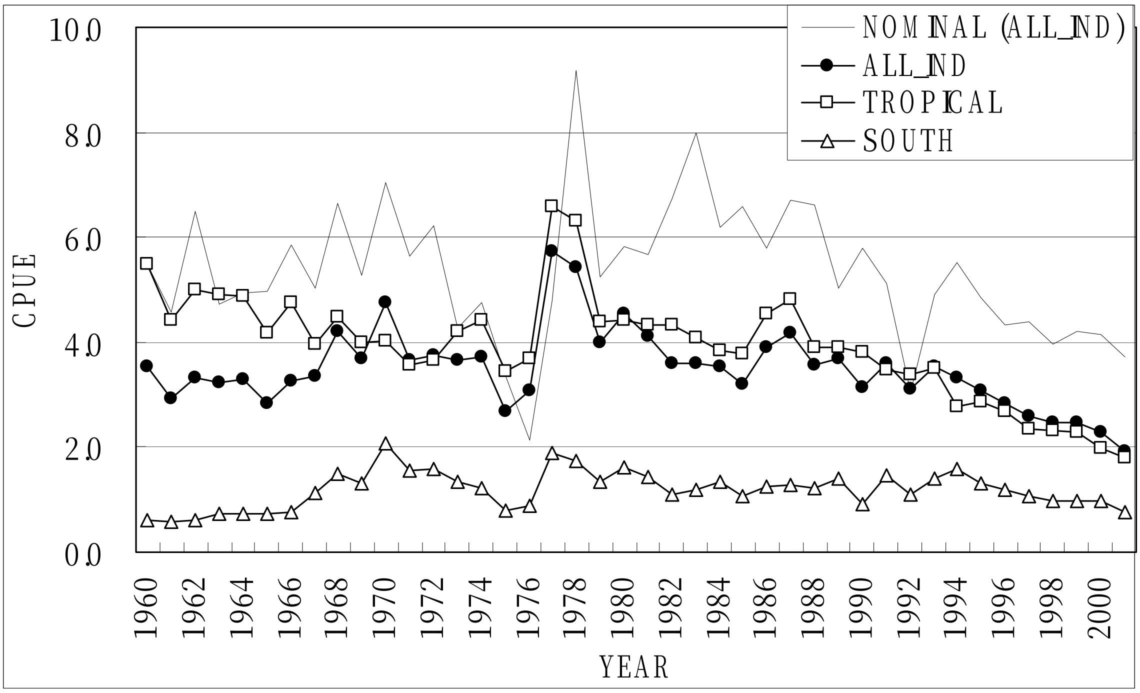

Fig. 6 Standardized CPUE expressed in real scale derived from GLM analysis using model_MLD for all Indian, Tropical and South areas with nominal CPUE of all Indian Ocean. Unit of CPUE is catch in number per 1000 hooks.