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Standardized CPUE of bigeye tuna (*Thunnus obesus*) based on the fine scale catch and effort data of the Japanese tuna longline fisheries operated in the Indian Ocean (1980- 2008)

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Abstract

We re-attempted to estimate of annual changes of abundance index of bigeye tuna in the Indian Ocean based on the fine scale catch and effort data in reference to the recent study for swordfish. The time series for 21 years (1980-2008) is corresponding with the available duration of the fine scale environmental data, which are combination of moon phase, Indian Ocean Index, temperature, salinity, thermocline depth, shear current and its amplitudes assigned to 1 by 1 degree and/or month. We found that the strongest effects were the factors related to temperature, salinity and thermocline depth, which explained 30.3 % of variance in the final model. The next and third dominant factors were the shear current associated factors (22.5 %) and main effects (19.5%; year, area and quarter), respectively. The large effects of environmental factors on nominal CPUE rather than the main factors are not observed in the CPUE standardization based on 5 by 5 degrees, which are similar to the results of swordfish.

Introduction

For the standardization of the longline CPUE, the advantage to use the fine scale catch and effort data incorporated with environmental information has been suggested in case of swordfish in recent study (Nishida and Wan 2009). Therefore, the same investigation was applied to BET this time around.

Materials and methods

Data

The data source and the compiling methods are almost same in the case of swordfish except for two points 1) the drop of environmental factors of TG and SG (Oceanic front of temperature and salinity, respectively) according to a lot of missing values in specific area especially in areas 5 and 6 (Figure 1), and 2) the changing sampled depth of temperature and salinity from the 45 m depth to the 205 m depth in accordance with the difference of the habitat depth of the two species (Table 1).

GLM analysis

The effects main (year, area and quarter) and environmental factors on bigeye catch were assessed using GLM procedure of SAS software (vers. 9.1, SAS Inst., Inc.). We intended to select the final model after variable selection with backward stepwise F test with a criterion of P-value = 0.05, however there was no drop of variable, therefore the full model was the final model. The details of this model are as follows;

Log (CPUE + c) = mean + yr + qua + area + main_line + branch + CNHBF + environmental factors + interaction + error

where,

c: constant (10 % of the nominal CPUE (number 1000 hooks^{-1})

yr: year effect

qua: quarter effect

area: sub area effect (see Figure 1)

main_line: effect of material of main line (nylon or others)

branch: effect of material of branch line (nylon or others)

CNHBF: categorized number of hooks between floats (NHBF)
7>=NHBF>=5 as CNHBF=1, 10>=NHBF>=8 as CNHBF=2,
13>=NHBF>=11 as CNHBF=3, 16>=NHBF>=14 as CNHBF=4,
19>=NHBF>=17 as CNHBF=5, 21>=NHBF>=20 as CNHBF=6 and
otherwise CNHBF=7.

environmental factors: (see Table 1)

Interaction: yr*qua, yr*area, qua*area, qua*main_line, area*main_line, area*branch, main_line*branch, qua*CNHBF, area*CNHBF, T205*qua, S205*qua, TD*qua, T205*area, S205*area, TD*area, SC*qua, AM*qua, SC*area, AM*area, qua*branch, mp*qua, mp*area, ioi*qua and ioi*area

Abundance Index

The annual nominal and standardized CPUE were calculated from the weighted average of the area indices. The weighting factors from area 1 to 7 are 0.0699, 0.0973, 0.1478, 0.1506, 0.1666, 0.1033, and 0.2645, respectively.

Results

The summary of the final model was shown in Table 2. Distribution of the standard residual was shown in Figure 2. In terms of composition of F value by the “category” in Table 2 represented the level of affecting nominal bigeye CPUE by categories (Figure 3). The strongest effects were found in the factors related to temperature, salinity and thermocline depth (env_at_catch), which explained 30.3 % of variance in the final model. The next and third dominant factors were shear current associated factors (22.5 %) and main effects (19.5%; year, area and quarter), respectively. The large effects of environmental factors on nominal CPUE rather than the main factors are not observed in the CPUE standardization based on 5 by 5 degrees, which are similar to the results of swordfish.

The annual changes of three abundance indices of the nominal and the standardized CPUE based on 1 by 1 degree (this study) and the standardized CPUE based on 5 by 5 degrees (Okamoto et al 2009) were compared (Table 3, Figure 4). The general trends of three indices were similar, which were downward from 1980 to 2001 and then became slightly upward. However, the large fluctuation during 1980’s and early 1990’s in the nominal CPUE was smoothed in two standardized indices. The standardized CPUE series by area and by quarter (but area weighting was not applied) were shown in Figure 5.

Acknowledgments

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Literature cited

Nishida T, Wan Sheng-Ping. 2009 Estimation of the Abundance Index (AI) of swordfish (*Xiphias gladius*) in the Indian Ocean based on the fine scale catch and effort data in the Japanese tuna longline fisheries (1980-2007). IOTC-2009-WPB7-08. 1 -14.

Okamoto H, Satoh K, Shono H. 2009. Japanese longline CPUE for bigeye tuna in the Indian Ocean up to 2008 standardized by GLM. IOTC-2009-WPTT11-05. 1- 21.

Table 1 Summary of the input data (catch, effort and environmental data)

Code	Meaning	Resolution	Unit	Sources
catch and effort	catch and effort	day 1 by 1 degree	catch; number of fish effort; number of hooks	NRIFSF, Japan
MP	moon phase	Day	0 (new moon) to 29.7(full of the moon)	Japan Metrological Agency
IOI	Indian Ocean Index (difference of the atmospheric pressure between Mahe and Darwin)	Month	hPa (hectopascal)	Marsac (IRD, France)
T205	temperature at 205 m		℃	NOAA, USA (NCEP)
S205	salinity at 205 m		PSU (Practical Salinity Unit)	
TD	thermocline depth		℃	compiled from NCEP
SC	shear current (current integrated from 5 to 205 m)	month 1 by 1 degree	cm s^{-1}	
AM	Amplitudes of the SC (different between minimum and maximum water column sampled)		cm s^{-1}	NOAA, USA (NCEP)

Table 2 Results of the final model. The abbreviation of "env_at _catch" means the environmental at catch.

Source	DF	Adj SS	Adj MS	F	P
Model	458	179246.96	391.37	574.37	<.0001
Error	462956	315453.80	0.68		
Corrected Total	463414	494700.75			

R-Square	Coeff Var	Root MSE	lcpue Mean
0.362	59.256	0.825	1.393

Table 2 Continued						
Source	DF	Adj SS	Adj MS	F	P	category
yr	28	4986.16	178.08	261.34	<.0001	main_factors
qua	3	45.48	15.16	22.25	<.0001	main_factors
area	6	1486.83	247.80	363.67	<.0001	main_factors
yr*qua	84	2829.36	33.68	49.43	<.0001	main_factors
yr*area	168	8512.05	50.67	74.36	<.0001	main_factors
qua*area	18	3192.88	177.38	260.32	<.0001	main_factors
T205	1	348.05	348.05	510.79	<.0001	env_at_catch
S205	1	45.28	45.28	66.46	<.0001	env_at_catch
TD	1	35.03	35.03	51.42	<.0001	env_at_catch
T205*qua	3	81.76	27.25	40.00	<.0001	env_at_catch
S205*qua	3	45.30	15.10	22.16	<.0001	env_at_catch
TD*qua	3	401.06	133.69	196.20	<.0001	env_at_catch
T205*area	6	384.26	64.04	93.99	<.0001	env_at_catch
S205*area	6	1514.58	252.43	370.46	<.0001	env_at_catch
TD*area	6	1020.48	170.08	249.61	<.0001	env_at_catch
SC	1	51.53	51.53	75.62	<.0001	shear_current
AM	1	540.29	540.29	792.92	<.0001	shear_current
SC*qua	3	52.83	17.61	25.84	<.0001	shear_current
AM*qua	3	20.68	6.89	10.11	<.0001	shear_current
SC*area	6	591.50	98.58	144.68	<.0001	shear_current
AM*area	6	582.91	97.15	142.58	<.0001	shear_current
mp	1	371.56	371.56	545.29	<.0001	moon_phase
mp*qua	3	9.57	3.19	4.68	0.0028	moon_phase
mp*area	6	80.94	13.49	19.80	<.0001	moon_phase
main_line	1	138.20	138.20	202.82	<.0001	line_materials
branch	1	60.50	60.50	88.79	<.0001	line_materials
main_line*branch	1	86.26	86.26	126.59	<.0001	line_materials
qua*main_line	3	76.16	25.39	37.26	<.0001	line_materials
area*main_line	6	160.16	26.69	39.18	<.0001	line_materials
qua*branch	3	31.17	10.39	15.25	<.0001	line_materials
area*branch	6	102.50	17.08	25.07	<.0001	line_materials
CNHBF	6	651.59	108.60	159.38	<.0001	targeting
qua*CNHBF	18	988.51	54.92	80.60	<.0001	targeting
area*CNHBF	36	1508.83	41.91	61.51	<.0001	targeting
ioi	1	19.49	19.49	28.61	<.0001	ioi
ioi*qua	3	17.10	5.70	8.37	<.0001	ioi
ioi*area	6	94.63	15.77	23.15	<.0001	ioi

Table 3 Annual changes of abundance indices of Japanese longline in the Indian Ocean

yr	nominal (1 by 1)	standardized (1 by 1)	standardized (5 by 5)
1980	1.481	1.446	1.270
1981	1.269	1.284	1.126
1982	1.641	1.321	1.279
1983	1.679	1.348	1.349
1984	1.379	1.243	1.060
1985	1.386	1.144	0.964
1986	1.440	1.316	1.107
1987	1.588	1.363	1.379
1988	1.404	1.265	1.159
1989	1.261	1.233	1.055
1990	1.785	1.231	1.000
1991	0.932	1.074	0.971
1992	0.702	0.951	0.932
1993	0.883	1.026	0.950
1994	0.877	1.006	0.883
1995	0.810	1.032	0.847
1996	0.755	1.010	0.832
1997	0.715	0.786	0.718
1998	0.711	0.920	0.822
1999	0.744	0.915	0.773
2000	0.692	0.884	0.703
2001	0.640	0.714	0.640
2002	0.583	0.608	0.556
2003	0.589	0.582	0.626
2004	0.605	0.650	0.719
2005	0.535	0.673	0.676
2006	0.541	0.657	0.628
2007	0.698	0.712	0.634
2008	0.673	0.606	0.633

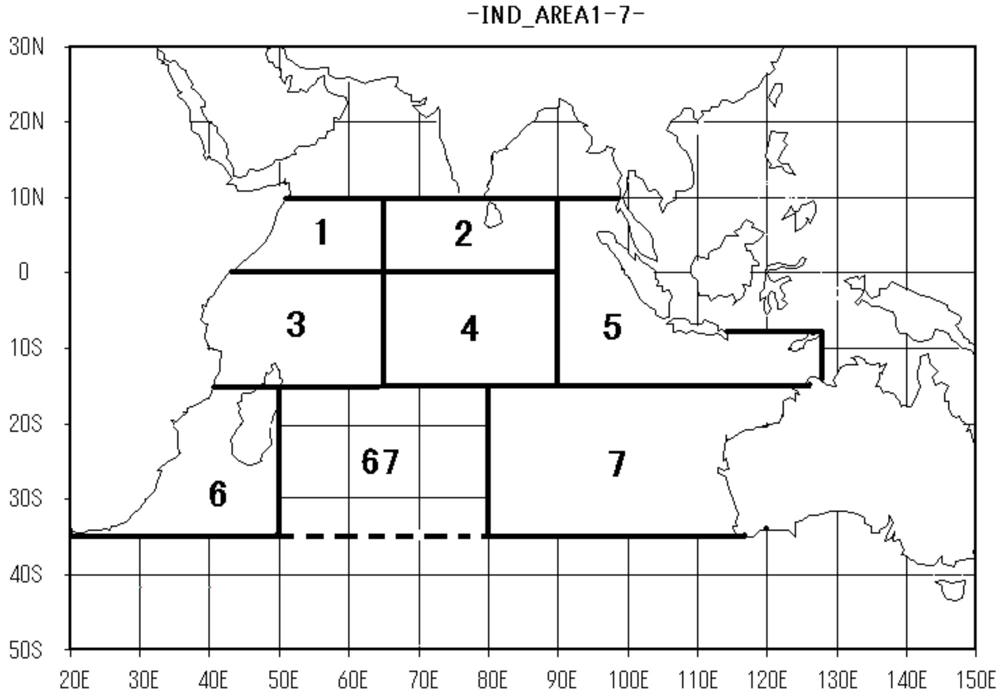

Figure 1 Area definition for the standarzation of Japanese longline CPUE in the Indian Ocean

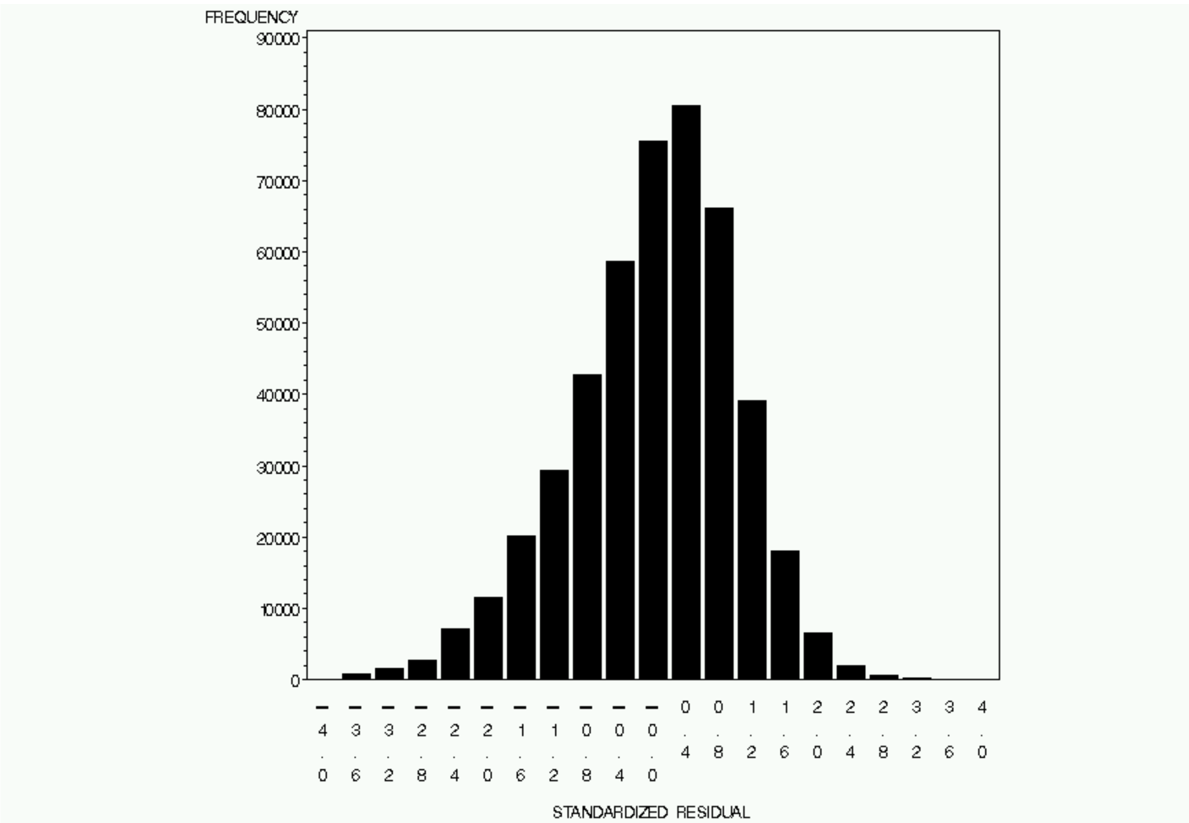

Figure 2 Standardized residuals of year based standardization expressed as histograms

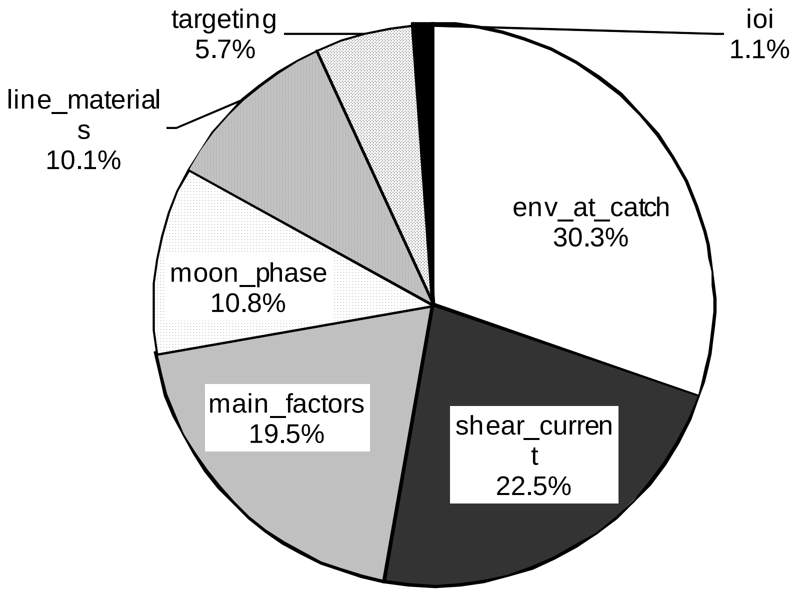

Figure 3 Factors affecting the bigeye nominal CPUE in terms of compositions of standardized F statistics

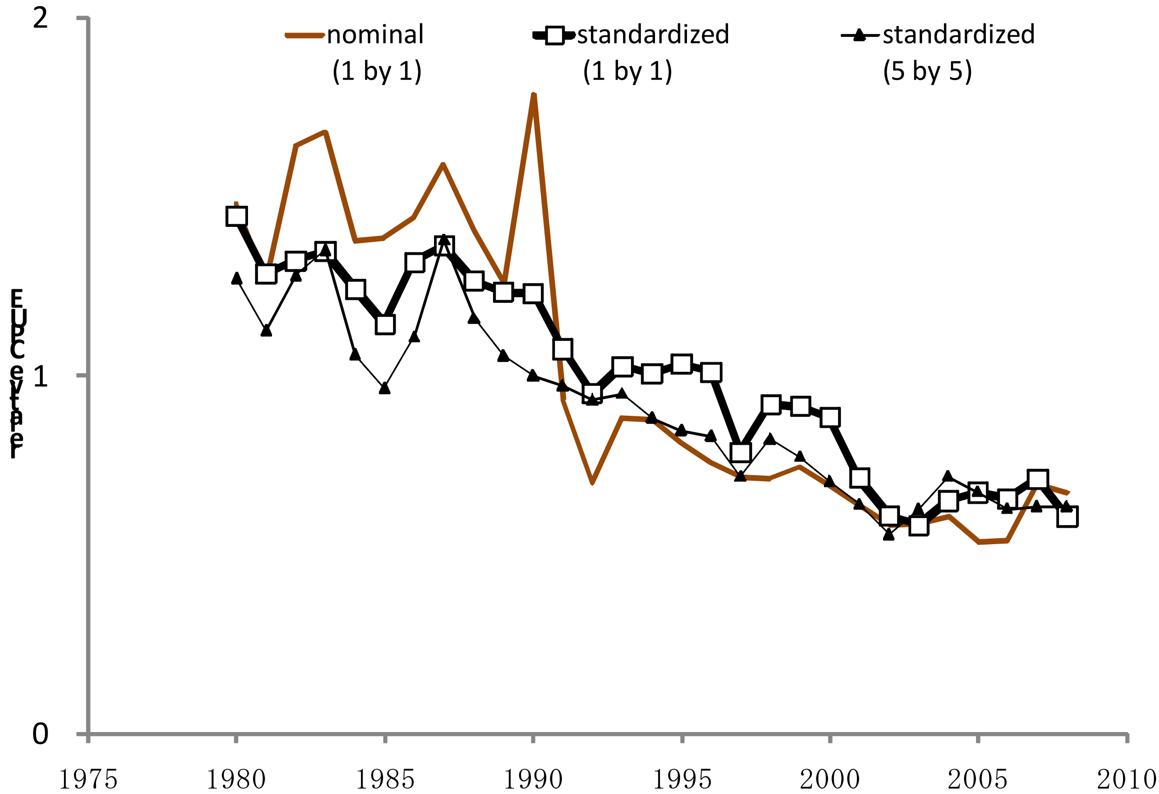

Figure 4 Comparison of three CPUE series of bigeye. Standardized CPUE based on 1 by 1 (open square), nominal CPUE 1 by 1 (solid line without marker), and standardized CPUE 5 by 5 (solid triangle) of Japanese longline in the Indian Ocean

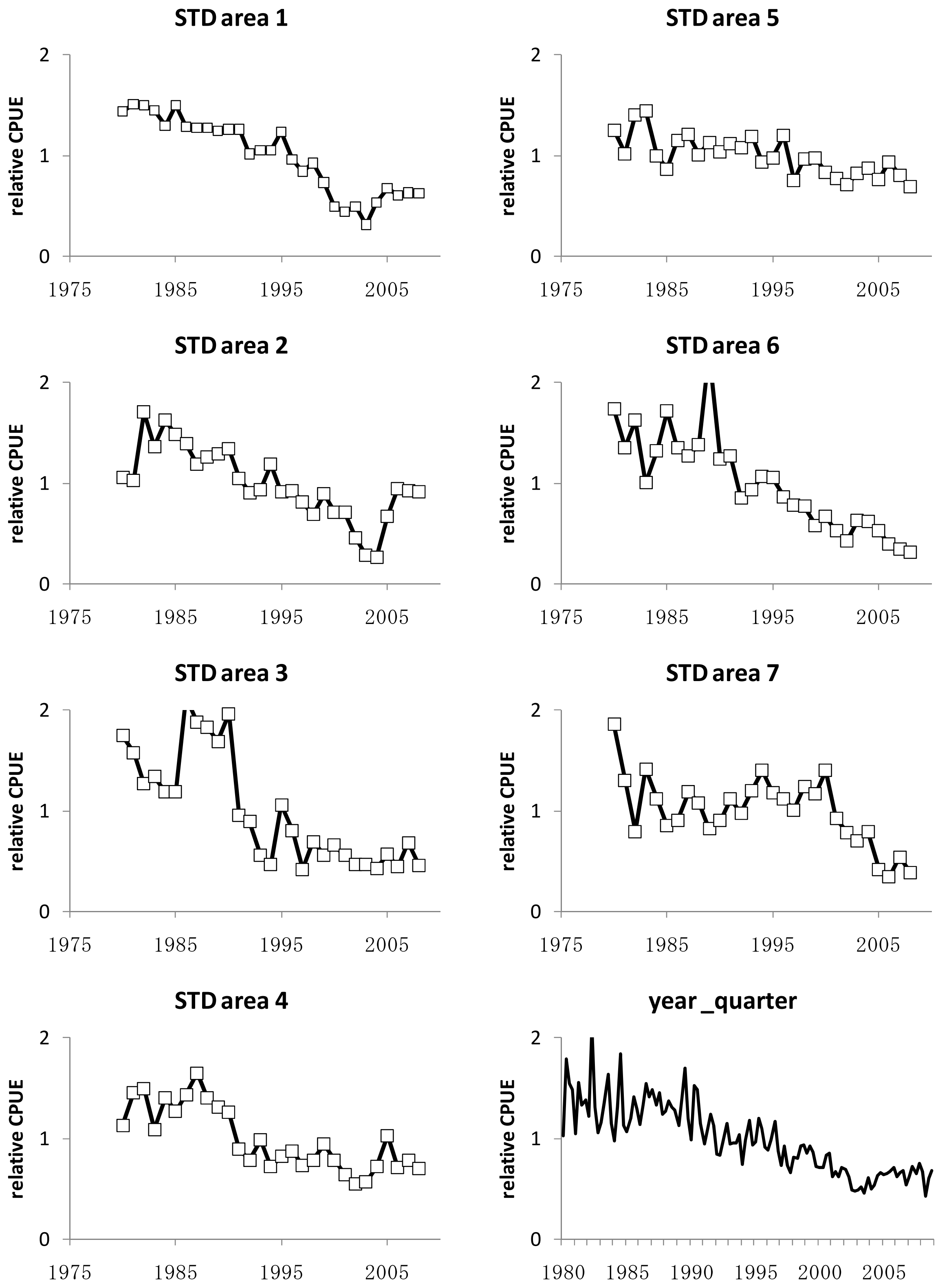

Figure 5 Standardized series by area of bigeye of Japanese longline in the Indian Ocean. Quarter based time series (lower right panel).