JAPANESE LONGLINE CPUE FOR YELLOWFIN TUNA (*THUNNUS ALBACARES*) IN THE ATLANTIC OCEAN STANDARDIZED USING GLM UP TO 2014

Keisuke Satoh[1], Takayuki Matsumoto[1]

SUMMARY

Japanese longline CPUE in number for yellowfin tuna caught in the Atlantic Ocean was standardized in quarter and annual base using GLM (General Linear Model) for the period from 1965 to 2014 in order to provide indicator of the stock. Annual CPUE in weight was also estimated from 1970 to 2014. During the period analyzed, standardized CPUEs for number was divided into four periods according to its level of CPUE, before 1979 (high), 1980-1991 (middle), 1992-2005 (low) and after 2006 (low to middle).

RÉSUMÉ

La CPUE palangrière japonaise en nombre d'albacores capturés dans l'océan Atlantique a été standardisée par trimestre et année à l'aide d'un GLM (modèle linéaire généralisé) pour la période 1965-2014 afin de fournir un indicateur du stock. La CPUE annuelle en poids a également été estimée de 1970 à 2014. Au cours de la période analysée, la CPUE standardisée en nombre a été divisée en quatre périodes en fonction du niveau de la CPUE, avant 1979 (élevé), 1980-1991 (moyen), 1992-2005 (faible) et après 2006 (faible à moyen).

RESUMEN

Se estandarizó la CPUE del palangre japonés en número de rabiles capturados en el océano Atlántico por trimestre y por año utilizando un GLM (Modelo lineal generalizado) para el periodo 1965-2014 para obtener un indicador del stock. También se estimó la CPUE anual en peso desde 1970 hasta 2014. Durante el periodo analizado, la CPUE estandarizada en número se dividió en cuatro periodos en función de su nivel, antes de 1979 (alta), 1980-1991 (media), 1992-2005 (baja) y después de 2006 (baja a media).

KEYWORDS

Atlantic, Yellowfin, Longline, Catch/effort

[1] National Research Institute of Far Seas Fisheries. 5-7-1 Orido Shimizu, Shizuoka-City, Shizuoka 424-8633, Japan. matumot@affrc.go.jp

1. Introduction

Longline is the only tuna-fishing gear deployed by Japan at present in the Atlantic Ocean, and yellowfin tuna is one of the target species (Anonymous, 2013). Fishing effort for Japanese longline fishery covers almost entire Atlantic (**Appendix Figure 1**), and yellowfin tuna is mainly caught in the tropical area (**Appendix Figure 2**).

Japanese longline CPUE for yellowfin in the Atlantic Ocean was standardized by GLM with lognormal error assumption up to 2014 in order to provide stock indicator of this species. For being easy to compare, the updated CPUE is calculated basically by the same method in previous studies (Okamoto and Satoh, 2008, Satoh et al., 2012 and Matsumoto and Satoh, 2015).

2. Materials and methods

2.1 Data

The Japanese longline catch (in number and in weight) and effort statistics from 1965 (from 1970 for weight data) to 2014 were used. Data for 2014 are preliminary. The catch and effort data set was aggregated by month, 5-degree square and the number of hooks between floats (NHBF). The data in which the number of hooks was less than 10,000 in a stratum were not used for analyses. The NHBF from 1965 to 1974 is not available from logbook, therefore the NHBF was regarded to be 5 for these years.

Area definition for the quarterly indices is whole Atlantic, east Atlantic and west Atlantic (**Figure 1**), and for the annual indices is consisted of three sub-areas (**Figure 2**). As environmental factor, the monthly SST (Sea Surface Temperature) data for 1-degree latitude and 1-degree longitude was obtained from NEAR-GOOS Regional Real Time Data Base of Japan Meteorological Agency (JMA; Monthly Mean Global Sea Surface Temperatures (COBE-SST), http://ds.data.jma.go.jp/gmd/goos/data/database.html). The SST data was averaged into 5-degree latitude and 5-latitude longitude by month from 1965 to 2014.

2.2 Model used for standardization

The initial annual and quarterly models are the same as those for the previous Japanese longline CPUE standardization analyses (Okamoto and Satoh, 2008, Satoh et al., 2012 and Matsumoto and Satoh, 2015). The effects of several factors on yellowfin catch were assessed using GLM procedure (log normal error structure model, SAS ver. 9.4, 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. In the cases in which the factor is not significant as main factor but is significant as interaction with other factor, the main factor was kept in the model.
For alternative model,

In order to explain two dimensional distributions of CPUE, the nonlinear relationship between SST and CPUE is applied into the model as explanation variables as SST^2 and SST^3. The interaction term between latitude (Lat) and longitude (Lon) was included in the model as the cubic expression (i.e., Lat + Lon + $(Lat + Lon)^2$ + (Lat + $Lon)^3$). The number of hooks between float (NHBF) were categorized into 5 classes (CNHBF 1: less than 6, CNHBF 2: 6-8, CNHBF 3: 9-12, CNHBF 4: 13-16, CNHBF 5: larger than 16). The details of the initial models are as follows;

For annual CPUE in number base and weight base
Log (CPUE +constant) = mean + year + month + area + CNHBF + SST + SST^2 + SST^3 + ML + BL + interaction + error

where	Log:	natural logarithm,
	CPUE:	catch in number (weight) of bigeye per 1000 hooks,
	constant:	10% of overall mean of CPUE
	mean:	overall mean,
	year:	effect of year,
	month:	effect of fishing season (month),
	area:	effect of sub-area (**Figure 2**),
	CNHBF:	effect of gear type (category of the number of hooks between floats),
	SST:	effect of SST (as a continuous variable),
	SST^2:	effect of SST^2 (=SST x SST, as a continuous variable),

SST^3: effect of SST^3 (=SST x SST x SST, as a continuous variable),
ML: effect of material of main line,
BL: effect of material of branch line,
Interaction: year*area + year*month + month*area + area*CNHBF + month*SST + month*SST + area*SST + CNHBF*SST + ML*CNHBF + BL*CNHBF
error: error term.

Effect of year was obtained by the method used in Ogura and Shono (1999) that uses lsmeans of year-area interaction as the following equation.

$$CPUE_i = \Sigma \ W_j * (\exp(\text{lsmean}(year_i * area_j)) - \text{constant}),$$

where $CPUE_i$ = CPUE in year i, W_j = area rate of area j; ($\Sigma W_j = 1$), lsmean ($year_i * area_j$) = least square mean of year * area interaction in $year_i$ and $area_j$, constant = 10% of overall mean of CPUE. As for the quarter based CPUE, least square mean of year*quarter*area was used instead. The sub-area is shown in **Figure 2**, which was used in last assessment in 2011.

For quarterly CPUE in number base

Log (CPUE + constant) = mean + year + quarter + Lat + Lon + Lat^2 + Lat-Lon + Lon^2 + Lat^3 + Lat^2-Lon + Lat-Lon^2 + Lon^3 + CNHBF + SST + SST^2 + SST^3 + ML + BL + error

Explanatory variables which is not included in the model for annual CPUE were included in the list as follows;

Where quarter: effect of fishing season (quarter)
Lat^2, Lat-Lon, Lon^2, Lat^3, Lat^2-Lon, Lat-Lon^2, Lon^3: the products of latitude (Lat) and longitude (Lon) expressed as third order polynomial functions. These values are included as continuous variables.
Interaction: year*quarter + quarter*SST + CNHBF*SST + ML + CNHBF + BL + CNHBF + quarter*Lat + quarter*Lat^2 + quarter*Lat^3 + quarter*Lon + quarter*Lon^2 + quarter*Lon^3 + CNHBF*Lat + CNHBF*Lat^2 + CNHBF*Lat^3 + CNHBF*Lon + CNHBF*Lon^2 + CNHBF*Lon^3 + SST*Lat + SST*Lat^2 + SST*Lat^3 + SST*Lon + SST*Lon^2 + SST*Lon^3

Error fixation

The wrong assignment of the area definition was fixed. In previous analyses (Okamoto and Satoh, 2008, Satoh et al., 2012 and Matsumoto and Satoh, 2015), the catch and effort in the range of 10-20W and 10-20S was wrongly assigned to the area 2 instead of the area 3 (**Figure 2**), and the missing catch and effort had occurred in the range for 10-20W and 20-40S, which accounted from 0.0 to 1.7% of the total effort (hooks), and from 0.0 to 0.2% of the total yellowfin catch in number.

The misspecification of the effort criteria for excluding data for GLM analysis was fixed. For quarterly index the criteria of 5,000 hook per a stratum had been used in the previous three studies instead of 10,000 hooks which was described in the text.

For the explanation quarterly CPUE index, in previous studies analyses there was certain error for the explanation of the model in regards to a series of latitudinal and longitudinal related variables (Lat-Lon, Lat^2-Lon and Lat-Lon^2), which were the products of two or three variables and were included as main effect, however in the previous documents there were explained as interaction variables instead.

3. Results and discussion

Annual CPUEs

Annual CPUEs in number and weight base standardized by GLM were shown in **Figure 3** in relative scale with nominal CPUE. In the relative scaled CPUE, average CPUE during the period analyzed (1965 (1970)-2014) was regarded as 1.0. ANOVA results were shown in **Table 1** and histograms and QQ-plots of standardized residual were shown in **Figure 4**. Distributions of the standard residual did not show remarkable difference from the normal distribution for both analyses. During the period analyzed, standardized CPUEs for number was divided into four periods according to its level of CPUE (before 1979 (high), 1980-1991 (middle), 1992-2005 (low) and after 2006 (low to middle)), whose average of standardized annual CPUEs of each group were significant different (Number; $F_{(3, 46)} = 47.38$, $P< 0.001$, post hoc HSD test, $P < 0.05$ for all combinations of the periods. Weight; $F_{(3, 41)} = 40.59$, $P< 0.001$, post hoc HSD test, $P < 0.05$ for all combinations of the periods., **Appendix Figure 3**). The weight base index also showed similar trend. The trends of these standardized CPUEs of previous studies and the present one were almost identical even though the fixation of errors (**Figure 5**).

Quarterly CPUEs

Trends of quarterly standardized and nominal CPUEs in number for all Atlantic and those divided into two areas were shown in **Figure 6**. Results of ANOVA and distributions of the standardized residual in each analysis were shown in **Table 2** and **Figure 7**, respectively. In both areas and whole Atlantic, seasonal oscillation in standardized CPUE was observed. The historical changes of CPUEs of last assessment and this study were quite similar (**Figure 8**).

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Table 1. ANOVA table for annual CPUE in weight (left) and number (right) standardized by log-normal error structured model. The area is defined in figure 2 in this report. CV, the coefficient of variation, which describes the amount of variation in the population, is 100 times the standard deviation estimate of the dependent variable (CPUE), Root MSE (Mean Square for Error), divided by the Mean.

Weight
Year
1970-2014

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square=
Model	693	20850.2	30.09	31.54	<.0001	0.37
Error	36686	34993.8	0.95			CV =
Corrected Total	37379	55843.9				26.03
year	44	596.1	13.5	14.2	<.0001	
month	11	117.9	10.7	11.2	<.0001	
area	2	157.1	78.6	82.4	<.0001	
CNHBF	4	118.2	29.6	31.0	<.0001	
sst	1	41.6	41.6	43.6	<.0001	
sst2	1	56.0	56.0	58.7	<.0001	
sst3	1	85.7	85.7	89.9	<.0001	
main	1	1.2	1.2	1.2	0.265	
bran	1	4.0	4.0	4.2	0.040	
year*area	88	787.9	9.0	9.4	<.0001	
year*month	484	2133.0	4.4	4.6	<.0001	
area*month	22	337.2	15.3	16.1	<.0001	
area*CNHBF	8	55.0	6.9	7.2	<.0001	
sst*month	11	120.2	10.9	11.5	<.0001	
sst*area	2	223.6	111.8	117.2	<.0001	
sst*CNHBF	4	166.2	41.5	43.6	<.0001	
main*CNHBF	4	43.9	11.0	11.5	<.0001	
bran*CNHBF	4	7.3	1.8	1.9	0.105	

Number
Year
1965-2014

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square=
Model	759	25006.1	32.95	36.28	<.0001	0.41
Error	38995	35409.1	0.91			CV =
Corrected Total	39754	60415.2				673.90
year	49	725.6	14.8	16.3	<.0001	
month	11	120.3	10.9	12.0	<.0001	
area	2	111.8	55.9	61.5	<.0001	
CNHBF	4	159.7	39.9	44.0	<.0001	
sst	1	75.7	75.7	83.4	<.0001	
sst2	1	100.5	100.5	110.7	<.0001	
sst3	1	143.8	143.8	158.3	<.0001	
main	1	0.2	0.2	0.2	0.633	
bran	1	21.8	21.8	24.0	<.0001	
year*area	98	1261.9	12.9	14.2	<.0001	
year*month	539	2265.4	4.2	4.6	<.0001	
area*month	22	323.9	14.7	16.2	<.0001	
area*CNHBF	8	67.7	8.5	9.3	<.0001	
sst*month	11	118.0	10.7	11.8	<.0001	
sst*area	2	202.7	101.4	111.6	<.0001	
sst*CNHBF	4	259.0	64.7	71.3	<.0001	
main*CNHBF	4	151.1	37.8	41.6	<.0001	
bran*CNHBF						

Table 2. ANOVA table for quarterly CPUE standardized by log-normal error structured model for each of two areas (west and east), which are defined in Figure 1 in this report. CV, the coefficient of variation, which describes the amount of variation in the population, is 100 times the standard deviation estimate of the dependent variable (CPUE), Root MSE (Mean Square for Error), divided by the Mean.

WEST

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square=
Model	277	11224.57	40.52	67.58	<.0001	0.60
Error	12678	7601.90	0.60	_	_	CV=
Corrected Total	12955	18826.46				120.31
year	49	478.13	9.76	16.27	<.0001	
quarter	3	15.21	5.07	8.46	<.0001	
lat	1	13.67	13.67	22.79	<.0001	
lon	1	14.04	14.04	23.41	<.0001	
lt2	1	5.81	5.81	9.7	0.002	
ltln	1	11.82	11.82	19.71	<.0001	
ln2	1	20.90	20.90	34.86	<.0001	
lt3						
lt2ln						
ltln2	1	14.03	14.03	23.41	<.0001	
ln3	1	35.44	35.44	59.1	<.0001	
CNHBF	4	22.35	5.59	9.32	<.0001	
sst	1	50.45	50.45	84.14	<.0001	
sst2	1	94.93	94.93	158.31	<.0001	
sst3						
main	1	0.04	0.04	0.06	0.800	
bran	1	0.14	0.14	0.24	0.627	
year*quarter	147	640.76	4.36	7.27	<.0001	
sst*quarter	3	17.66	5.89	9.82	<.0001	
sst*CNHBF	4	73.61	18.40	30.69	<.0001	
main*CNHBF	4	11.42	2.85	4.76	0.001	
bran*CNHBF	4	8.50	2.13	3.54	0.007	
lat*quarter	3	38.16	12.72	21.21	<.0001	
lt2*quarter	3	44.96	14.99	25	<.0001	
lt3*quarter	3	36.97	12.32	20.55	<.0001	
lon*quarter	3	14.35	4.78	7.97	<.0001	
ln2*quarter	3	16.83	5.61	9.36	<.0001	
ln3*quarter	3	17.94	5.98	9.97	<.0001	
lat*CNHBF	4	46.01	11.50	19.18	<.0001	
lt2*CNHBF	4	72.25	18.06	30.13	<.0001	
lt3*CNHBF	4	88.67	22.17	36.97	<.0001	
lon*CNHBF	4	49.07	12.27	20.46	<.0001	
ln2*CNHBF	4	36.76	9.19	15.33	<.0001	
ln3*CNHBF	4	26.36	6.59	10.99	<.0001	
lat*sst	1	13.25	13.25	22.1	<.0001	
lt2*sst	1	3.13	3.13	5.22	0.022	
lt3*sst						
sst*lt3	1	3.99	3.99	6.65	0.010	
ln2*sst	1	32.10	32.10	53.53	<.0001	
ln3*sst	1	41.22	41.22	68.75	<.0001	

EAST

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square=
Model	280	21818.94	77.92	85.07	<.0001	0.45
Error	28908	26479.83	0.92	0	0	CV=
Corrected Total	29188	48298.77				-307.31
year	49	1160.59	23.69	25.86	<.0001	
quarter	3	147.10	49.03	53.53	<.0001	
lat	1	223.15	223.15	243.61	<.0001	
lon	1	38.60	38.60	42.14	<.0001	
lt2	1	267.87	267.87	292.43	<.0001	
ltln	1	61.19	61.19	66.81	<.0001	
ln2	1	49.03	49.03	53.52	<.0001	
lt3	1	226.75	226.75	247.54	<.0001	
lt2ln	1	82.53	82.53	90.1	<.0001	
ltln2	1	5.26	5.26	5.74	0.017	
ln3	1	65.74	65.74	71.77	<.0001	
CNHBF	4	169.86	42.47	46.36	<.0001	
sst	1	34.83	34.83	38.02	<.0001	
sst2	1	31.96	31.96	34.89	<.0001	
sst3	1	39.56	39.56	43.18	<.0001	
main	1	14.43	14.43	15.75	<.0001	
bran	1	1.38	1.38	1.51	0.219	
year*quarter	147	1128.58	7.68	8.38	<.0001	
sst*quarter	3	172.88	57.63	62.91	<.0001	
sst*CNHBF	4	260.53	65.13	71.1	<.0001	
main*CNHBF	4	75.16	18.79	20.51	<.0001	
bran*CNHBF	4	10.77	2.69	2.94	0.019	
lat*quarter	3	39.82	13.27	14.49	<.0001	
lt2*quarter	3	37.06	12.35	13.49	<.0001	
lt3*quarter	3	65.44	21.81	23.81	<.0001	
lon*quarter	3	35.24	11.75	12.83	<.0001	
ln2*quarter	3	28.00	9.33	10.19	<.0001	
ln3*quarter	3	25.39	8.46	9.24	<.0001	
lat*CNHBF	4	126.74	31.68	34.59	<.0001	
lt2*CNHBF	4	128.98	32.24	35.2	<.0001	
lt3*CNHBF	4	114.36	28.59	31.21	<.0001	
lon*CNHBF	4	98.93	24.73	27	<.0001	
ln2*CNHBF	4	123.50	30.87	33.71	<.0001	
ln3*CNHBF	4	118.68	29.67	32.39	<.0001	
lat*sst	1	263.80	263.80	287.99	<.0001	
lt2*sst	1	249.31	249.31	272.17	<.0001	
lt3*sst	1	163.73	163.73	178.74	<.0001	
lon*sst	1	42.96	42.96	46.9	<.0001	
ln2*sst	1	45.84	45.84	50.05	<.0001	
ln3*sst	1	62.57	62.57	68.31	<.0001	

ALL

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square=
Model	271	31795.77	117.33	135.82	<.0001	0.47
Error	41873	36172.09	0.86	_	_	CV=
Corrected Total	42144	67967.86				2894.38
year	49	1025.59	20.93	24.23	<.0001	
quarter	3	125.29	41.76	48.34	<.0001	
lat	1	160.42	160.42	185.7	<.0001	
lon	1	213.61	213.61	247.28	<.0001	
lt2	1	46.98	46.98	54.39	<.0001	
ltln						
ln2	1	54.93	54.93	63.59	<.0001	
lt3	1	2.14	2.14	2.48	0.116	
lt2ln	1	179.07	179.07	207.3	<.0001	
ltln2	1	194.82	194.82	225.52	<.0001	
ln3	1	32.35	32.35	37.45	<.0001	
CNHBF	4	190.12	47.53	55.02	<.0001	
sst	1	7.55	7.55	8.74	0.003	
sst2	1	5.22	5.22	6.04	0.014	
sst3	1	10.34	10.34	11.97	0.001	
main	1	18.55	18.55	21.47	<.0001	
bran	1	35.72	35.72	41.35	<.0001	
year*quarter	147	1173.34	7.98	9.24	<.0001	
sst*quarter	3	135.21	45.07	52.17	<.0001	
sst*CNHBF	4	284.76	71.19	82.41	<.0001	
main*CNHBF	4	297.31	74.33	86.04	<.0001	
bran*CNHBF						
lat*quarter	3	68.17	22.72	26.31	<.0001	
lt2*quarter	3	79.26	26.42	30.58	<.0001	
lt3*quarter						
lon*quarter	3	101.61	33.87	39.21	<.0001	
ln2*quarter	3	60.16	20.05	23.21	<.0001	
ln3*quarter	3	37.83	12.61	14.6	<.0001	
lat*CNHBF	4	301.84	75.46	87.35	<.0001	
lt2*CNHBF	4	312.28	78.07	90.37	<.0001	
lt3*CNHBF	4	295.85	73.96	85.62	<.0001	
lon*CNHBF	4	9.17	2.29	2.66	0.031	
ln2*CNHBF	4	57.23	14.31	16.56	<.0001	
ln3*CNHBF	4	115.48	28.87	33.42	<.0001	
lat*sst	1	162.52	162.52	188.14	<.0001	
lt2*sst	1	19.47	19.47	22.54	<.0001	
lt3*sst	1	5.30	5.30	6.13	0.013	
lon*sst	1	86.54	86.54	100.18	<.0001	
ln2*sst						
ln3*sst	1	82.43	82.43	95.42	<.0001	

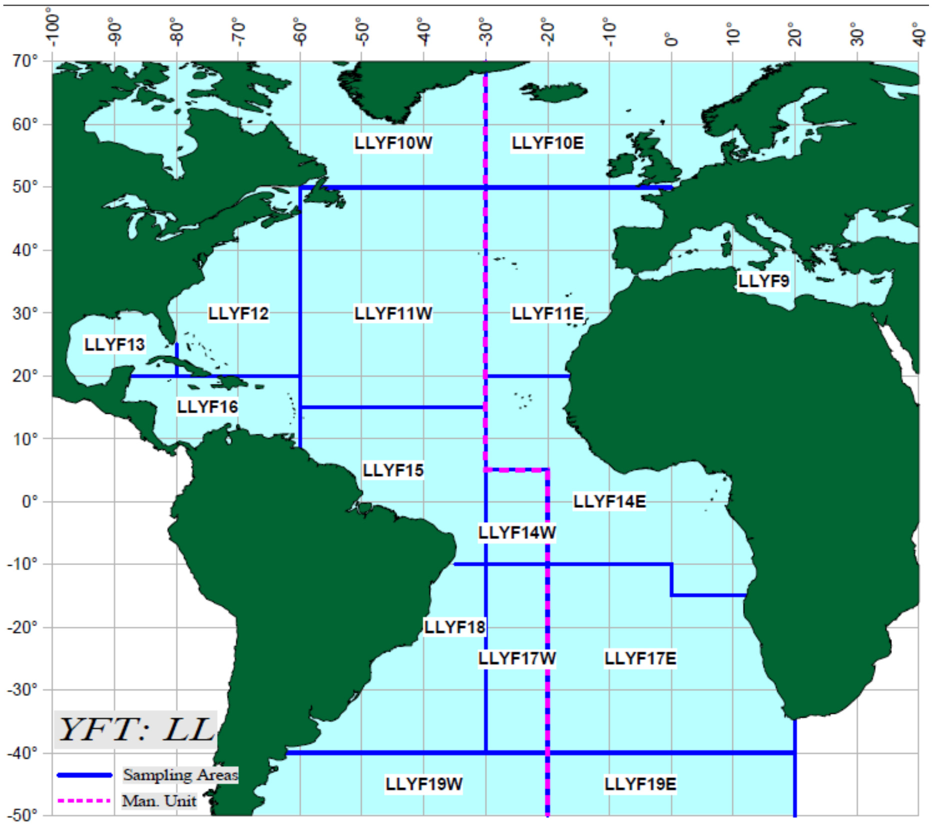


Figure 1. Area definition (west and east are divided by pink dashed line) which is used in yellowfin stock assessment using Multifan-CL (from http://www.iccat.int/Data/ICCATMaps2011.pdf).

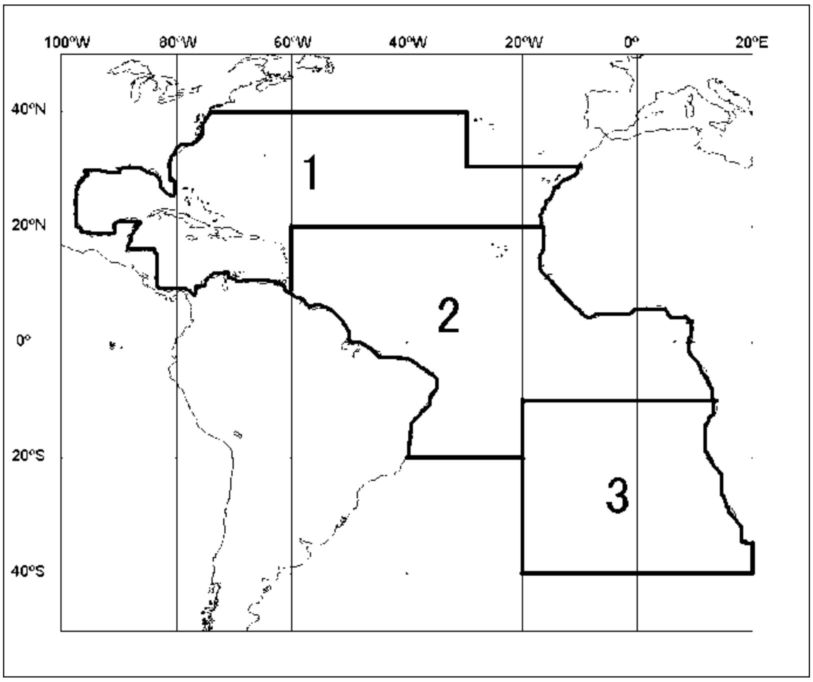
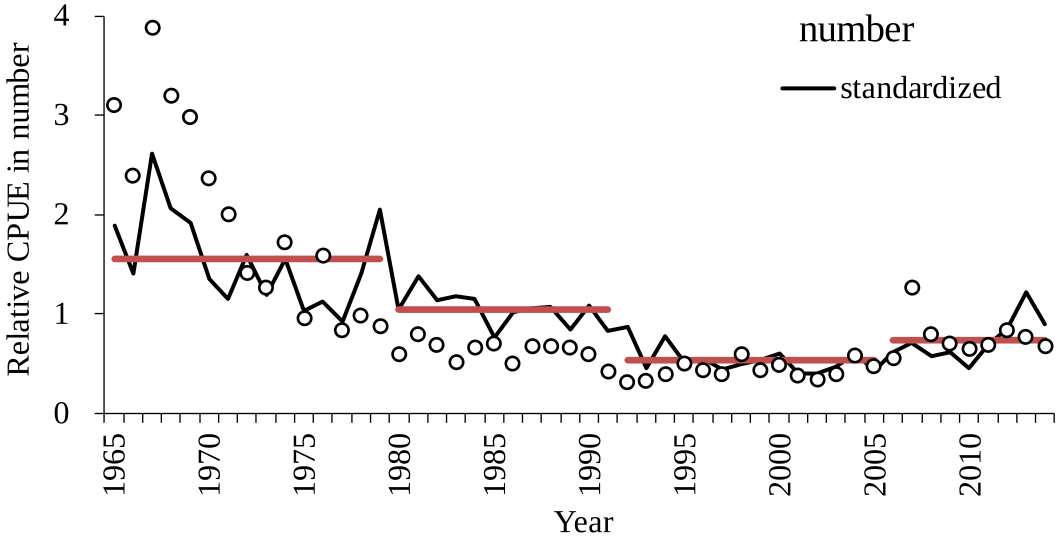


Figure 2. Sub-area definitions used for Japanese longline CPUE standardization, which is the same as that in last yellowfin assessment (Okamoto and Satoh, 2008; Satoh et al., 2012; Matsumoto and Satoh, 2015). However, in these previous studies the catch and effort in the range of 10-20W and 10-20S was wrongly assigned to the area 2 instead of the area 3, and the missing catch and effort had occurred in the range for 10-20W and 20-40S in the CPUE standardization program.



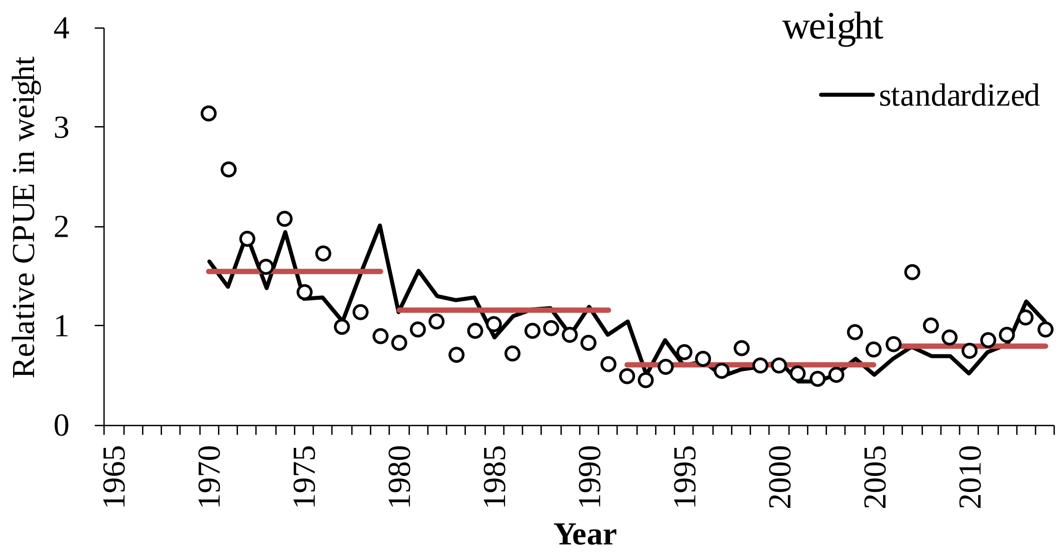


Figure 3. Standardized (solid line) and nominal (open circle) annual CPUE in number (top) and weight (bottom) expressed in relative scale in which the average from 1965 (1970) to 2014 is 1.0. The red lines present the average of the standardized CPUE for each period (before 1979, 1980-1991, 1992-2005 and after 2006).

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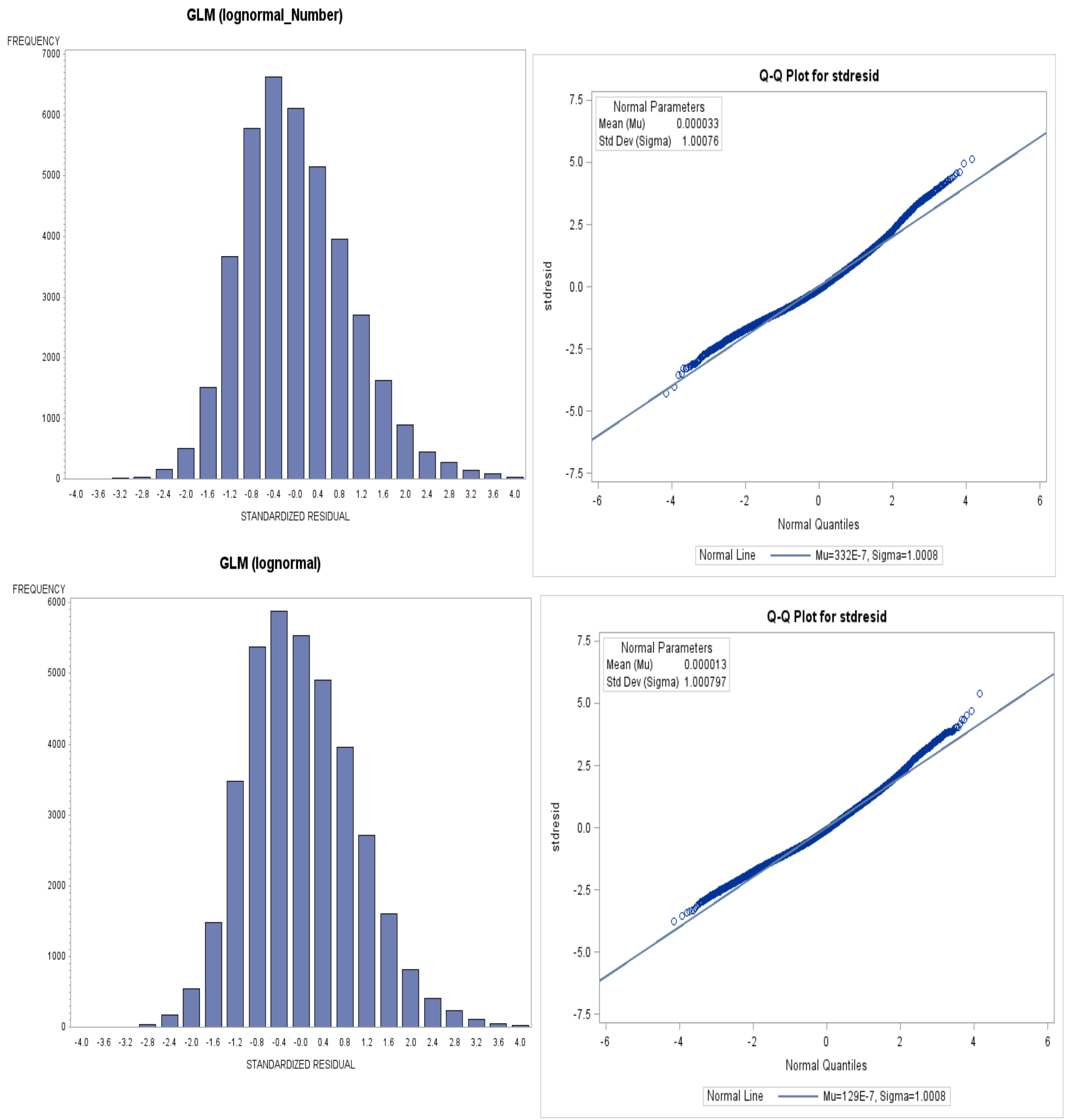


Figure 4. Overall histogram and QQ-plot of standardized residuals from the GLM analyses for annual CPUEs in number (upper) and weight (bottom) applying the final model in this study.

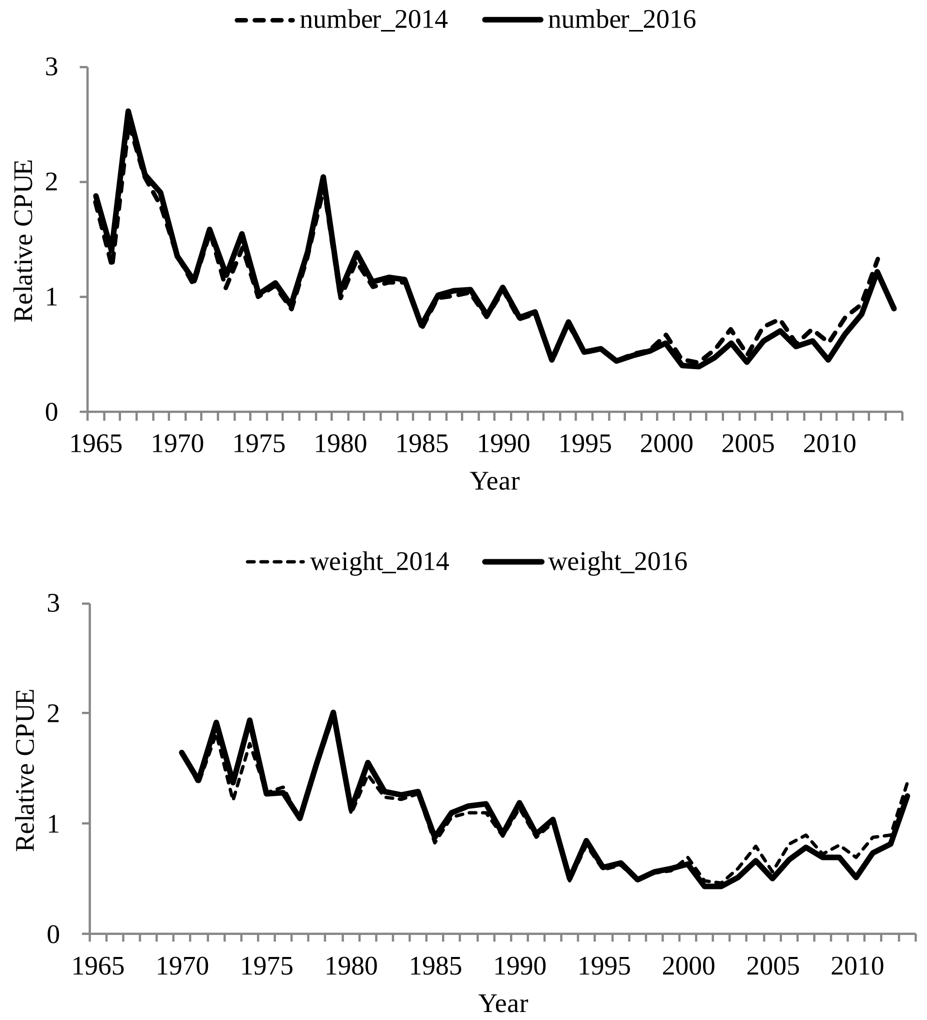


Figure 5. Comparison of standardized CPUE between last one of SCRS tropical tuna meeting in 2014 (dashed line) and this study (solid line) in number (upper) and weight (bottom) base.

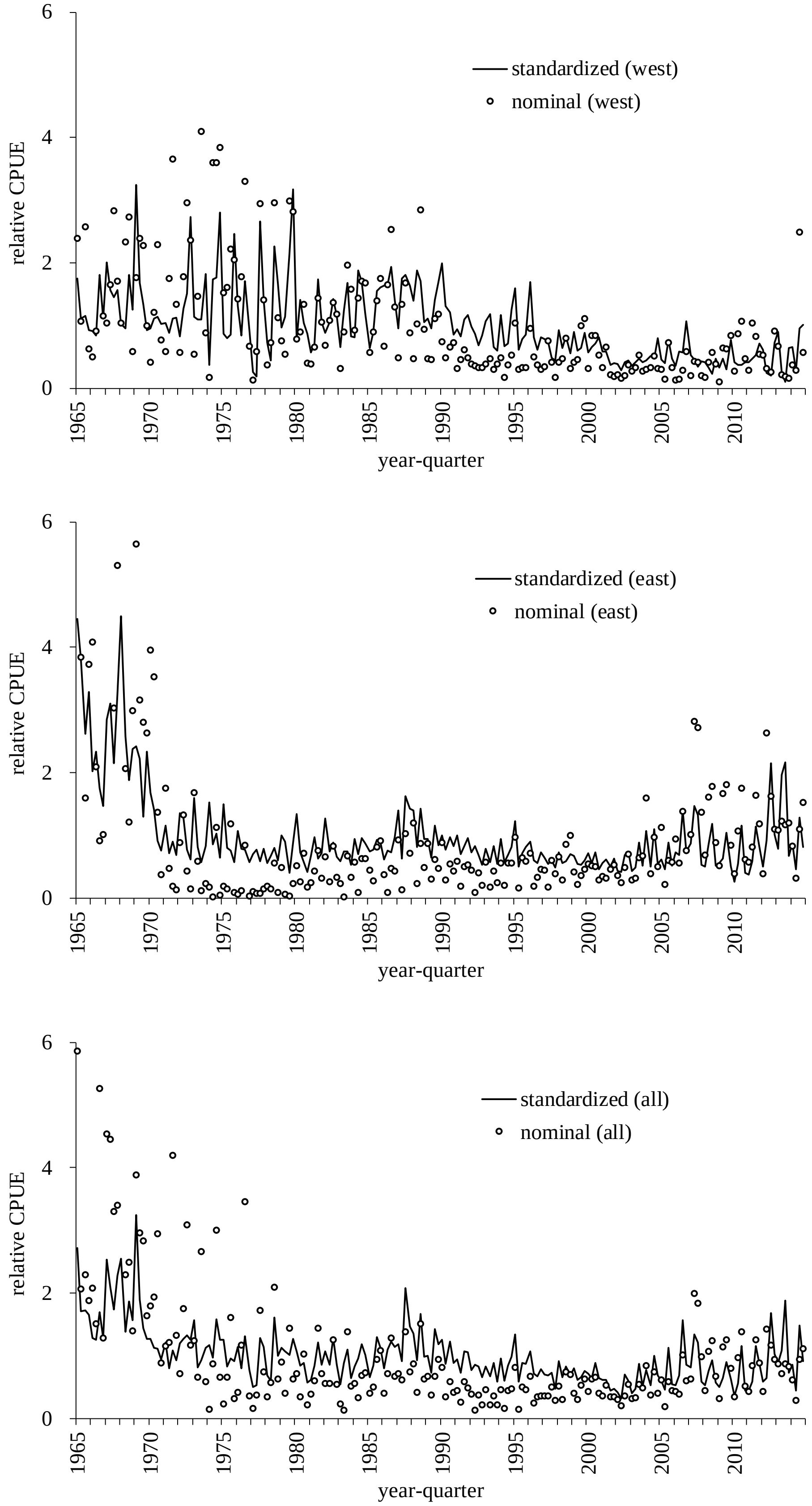


Figure 6. Standardized (solid line) and nominal (open circle) quarterly CPUEs in number for west, east and all Atlantic Ocean in relative scale in which the average from 1965 to 2014 is 1.0.

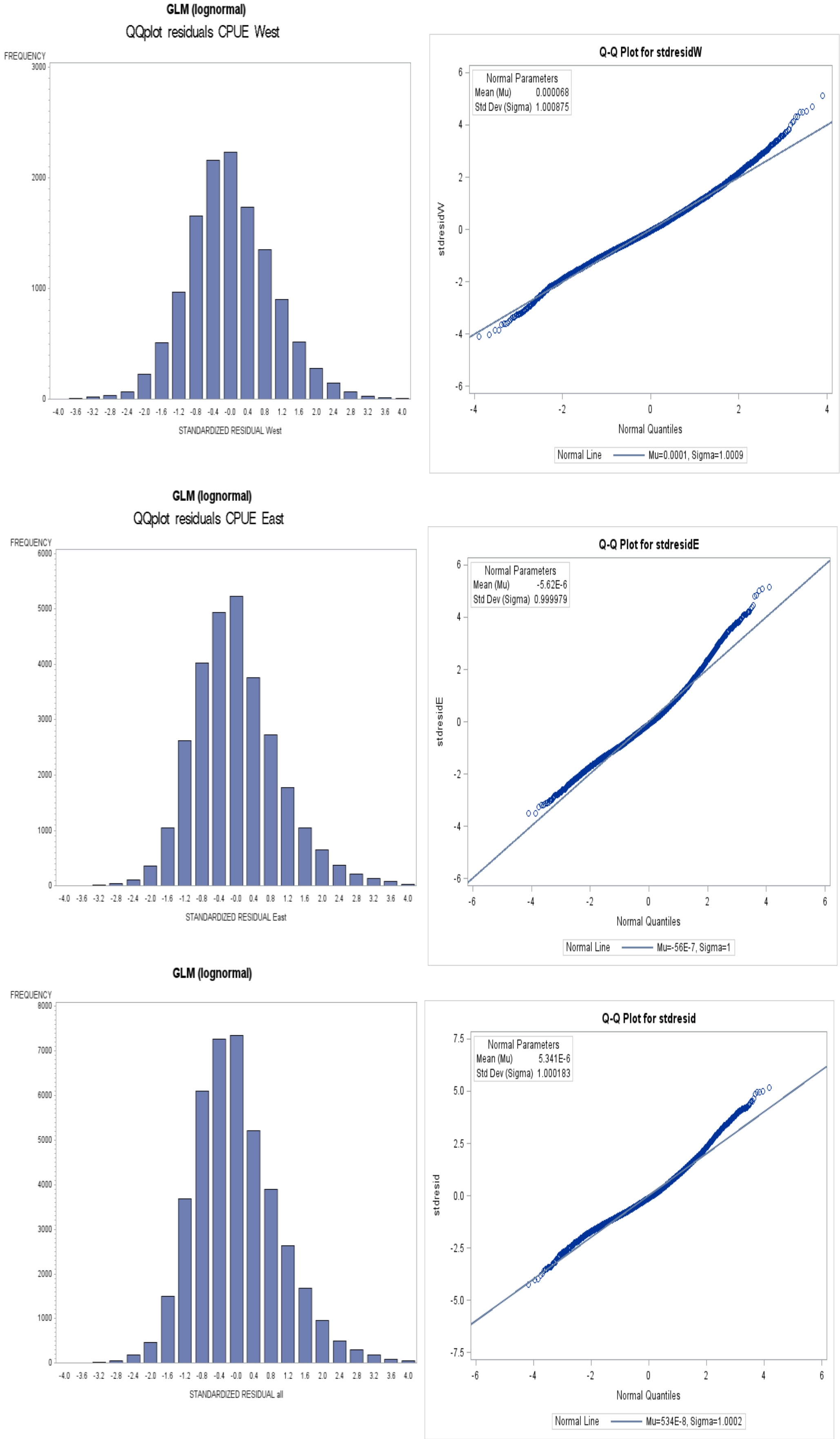


Figure 7. Overall histogram and QQ-plot of standard residuals from the GLM analyses for quarterly CPUE in west (top), east (middle) and all (bottom) Atlantic Ocean of the final model in this study.

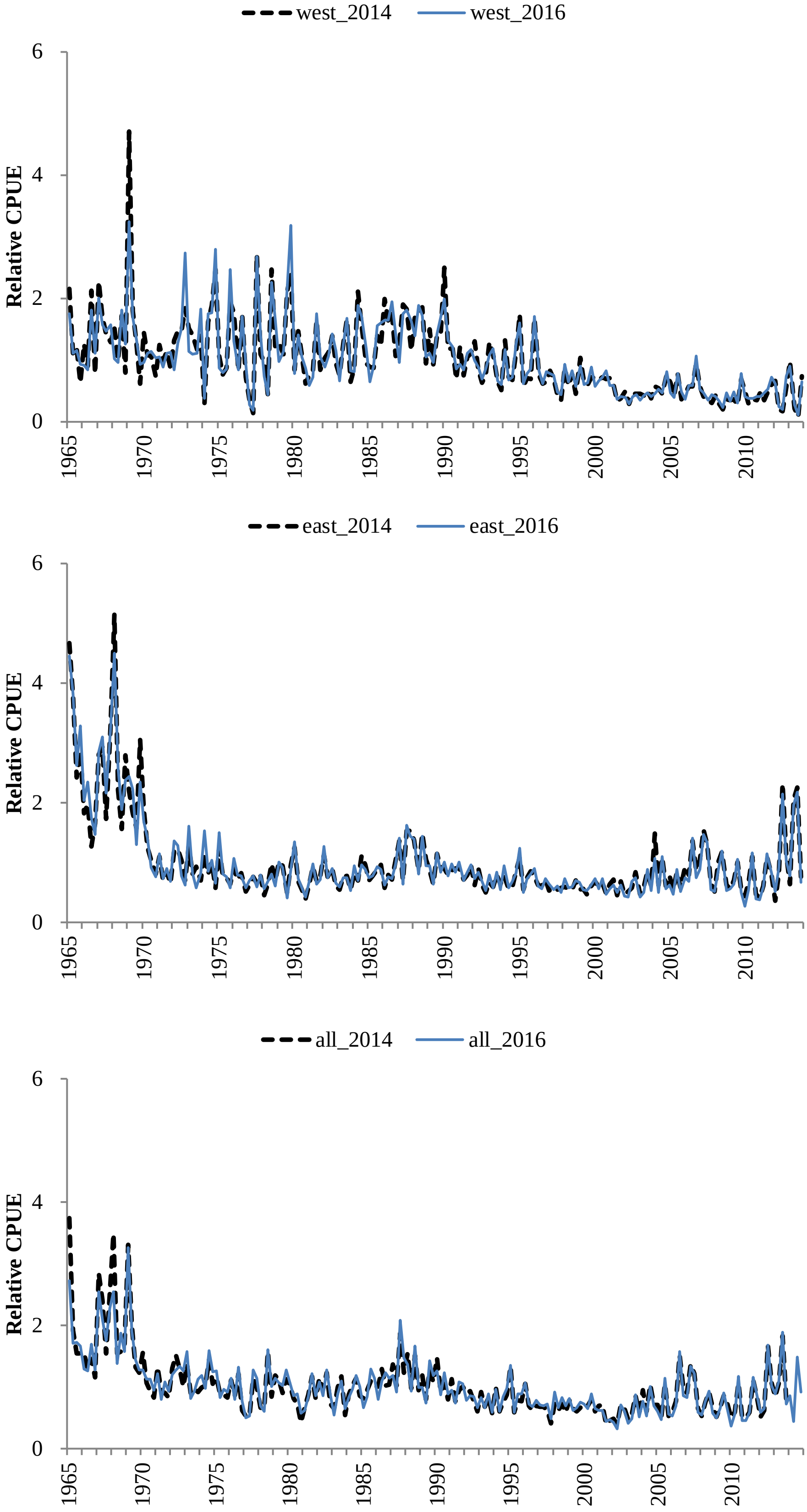
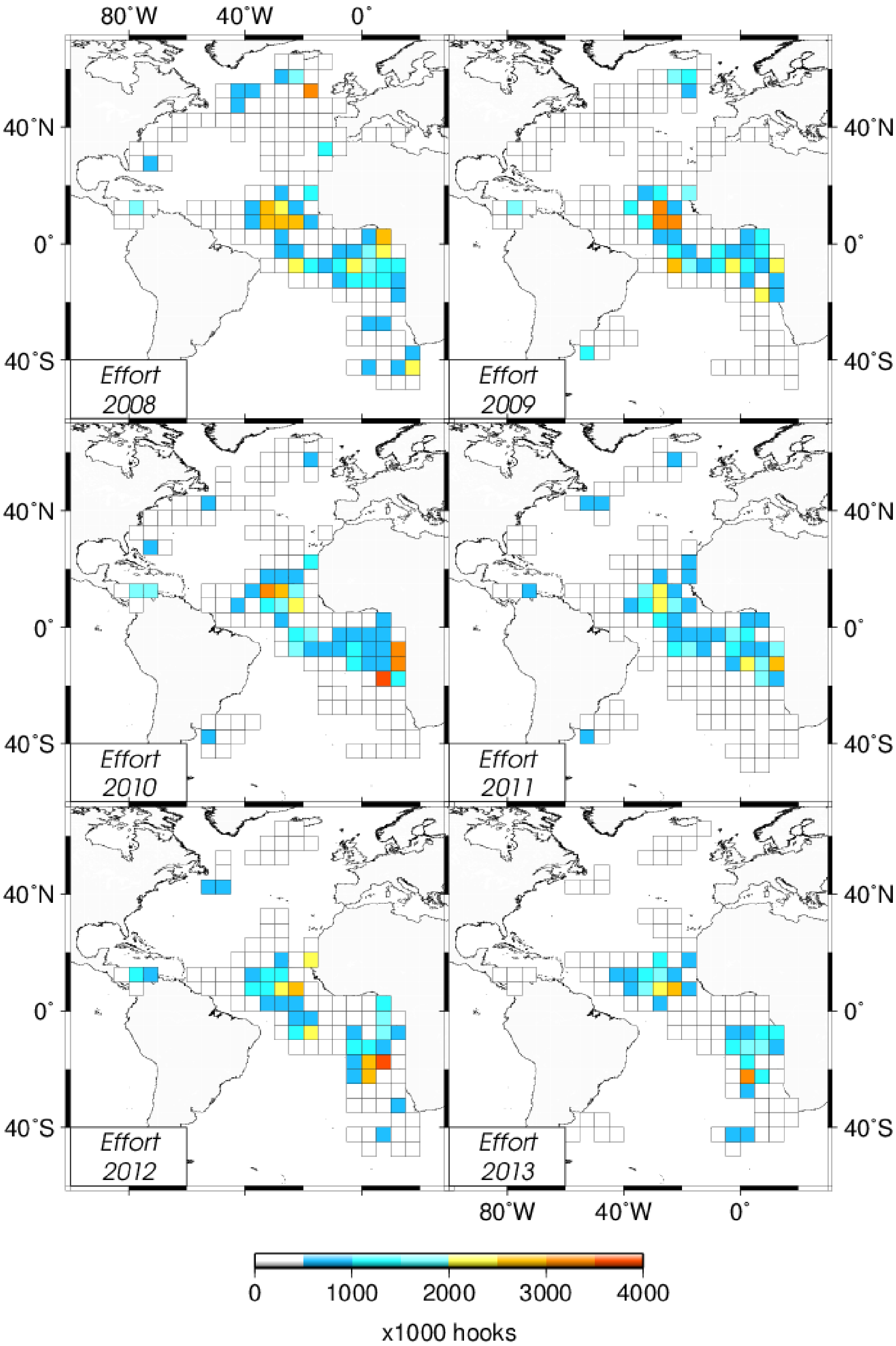
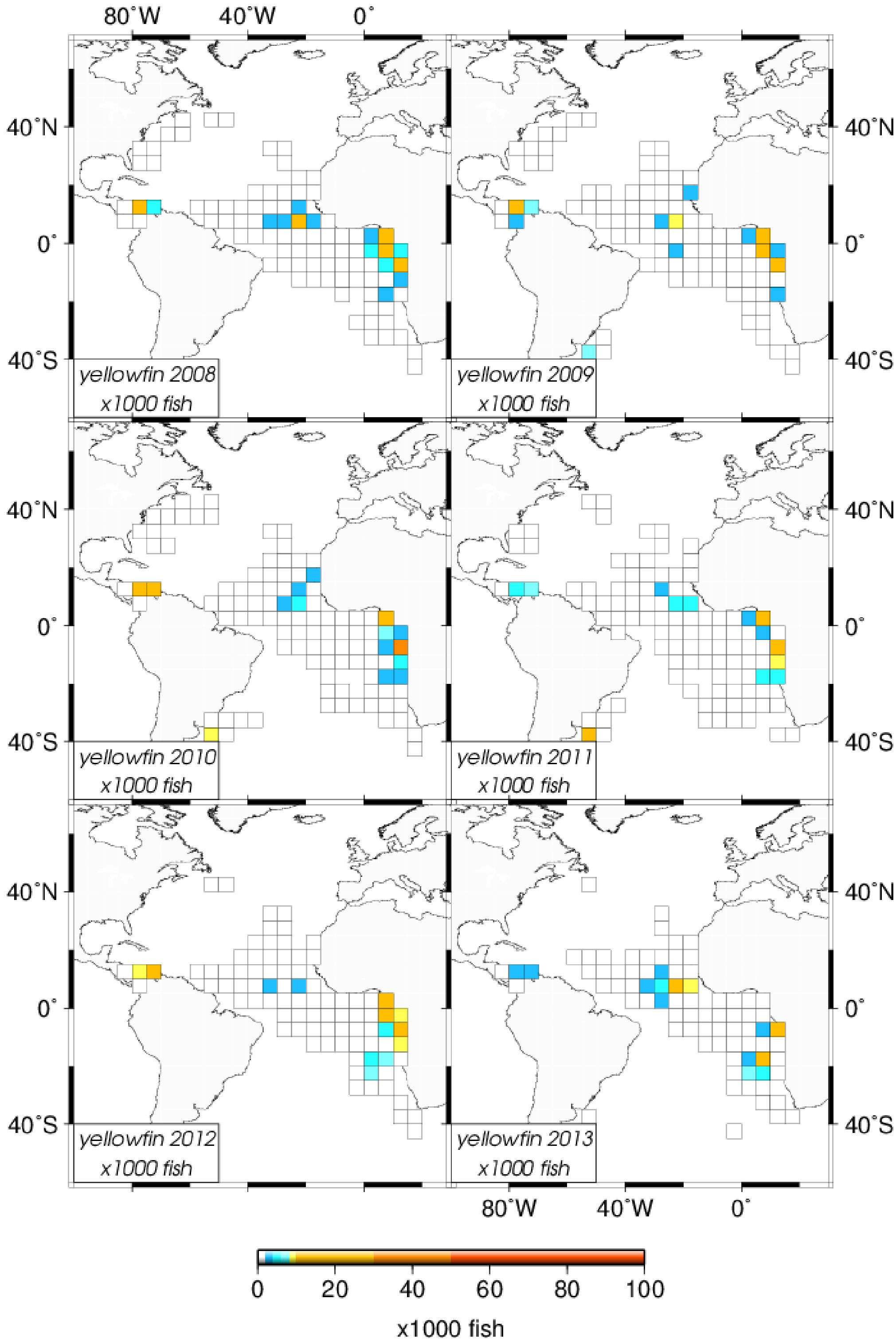


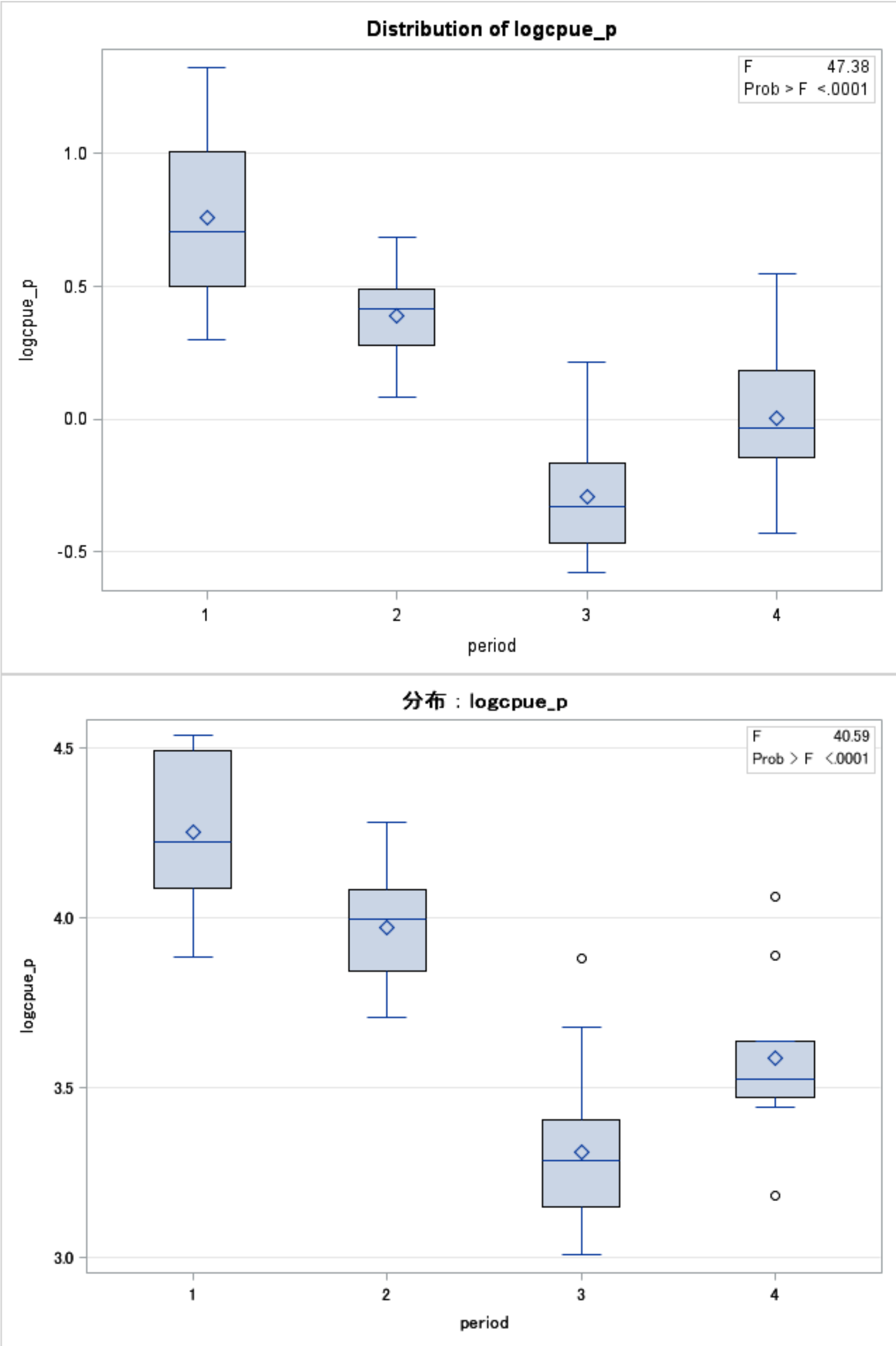
Figure 8. Comparison of standardized CPUE between last one of SCRS tropical tuna meeting in 2014 (dashed line) and this study (solid line) in west (upper), east (middle) and all (bottom) Atlantic Ocean.



Appendix Figure 1. Geographical distribution of fishing effort for Japanese longline fishery in recent years.



Appendix Figure 2 Geographical distribution of yellowfin catch by Japanese longline fishery in recent years.



Appendix Figure 3. Differences of distribution of average standardized annual CPUE (natural log transformed real scale) in number (upper) and in weight (bottom) of yellowfin tuna caught by Japanese longline in the Atlantic Ocean among periods (before 1979, 1980-1991, 1992-2005 and after 2006.

Appendix Table 1. Nominal and standardize CPUE in number (number of fish per 1000 hooks) in real scale and relative scale in which the average from 1965 to 2014 is 1.0. The point in real scale is calculated by exp (lsmean)-mean/10, the upper is calculated as exp (lsmean+1.96*standard error)-mean/10, the lower is calculated by exp (lsmean-1.96 standard error)-mean/10. The lsmean is least square means of "year effect". These values are conditioned by the area effect as mentioned in the text.

CPUE in number

Year	nominal		standardized			
	real scale	relative scale	real scale			relative scale
			upper	point	lower	
1965	10.174	2.680	2.236	2.680	3.206	1.885
1966	7.853	1.992	1.598	1.992	2.471	1.401
1967	12.709	3.723	2.999	3.723	4.615	2.619
1968	10.459	2.935	2.346	2.935	3.663	2.065
1969	9.793	2.715	2.136	2.715	3.439	1.910
1970	7.741	1.925	1.512	1.925	2.436	1.354
1971	6.566	1.629	1.305	1.629	2.022	1.146
1972	4.619	2.259	1.734	2.259	2.924	1.589
1973	4.161	1.695	1.248	1.695	2.275	1.192
1974	5.631	2.207	1.509	2.207	3.205	1.553
1975	3.133	1.460	1.150	1.460	1.839	1.027
1976	5.203	1.605	1.216	1.605	2.100	1.129
1977	2.732	1.323	0.974	1.323	1.770	0.930
1978	3.209	1.991	1.513	1.991	2.598	1.400
1979	2.851	2.914	2.232	2.914	3.783	2.050
1980	1.954	1.489	1.197	1.489	1.842	1.047
1981	2.594	1.965	1.642	1.965	2.344	1.382
1982	2.250	1.610	1.320	1.610	1.959	1.133
1983	1.688	1.670	1.281	1.670	2.160	1.175
1984	2.148	1.638	1.311	1.638	2.038	1.152
1985	2.320	1.081	0.881	1.081	1.320	0.761
1986	1.660	1.448	1.142	1.448	1.825	1.019
1987	2.214	1.496	1.202	1.496	1.853	1.052
1988	2.215	1.521	1.241	1.521	1.857	1.070
1989	2.155	1.200	1.007	1.200	1.425	0.844

Appendix Table 1 (continue)

Year	CPUE in number					
	nominal		standardized			
	real scale	relative scale	real scale			relative scale
			upper	point	lower	
1990	1.938	1.547	1.256	1.547	1.898	1.088
1991	1.374	1.174	0.942	1.174	1.456	0.826
1992	1.012	1.235	0.968	1.235	1.567	0.869
1993	1.078	0.653	0.511	0.653	0.826	0.459
1994	1.279	1.109	0.851	1.109	1.443	0.780
1995	1.645	0.737	0.608	0.737	0.887	0.518
1996	1.421	0.783	0.658	0.783	0.925	0.551
1997	1.280	0.631	0.524	0.631	0.754	0.444
1998	1.929	0.709	0.596	0.709	0.837	0.499
1999	1.415	0.760	0.628	0.760	0.913	0.535
2000	1.577	0.857	0.722	0.857	1.011	0.602
2001	1.268	0.578	0.469	0.578	0.704	0.407
2002	1.133	0.564	0.449	0.564	0.698	0.397
2003	1.271	0.674	0.557	0.674	0.809	0.474
2004	1.924	0.860	0.722	0.860	1.018	0.605
2005	1.548	0.617	0.503	0.617	0.749	0.434
2006	1.808	0.875	0.724	0.875	1.051	0.616
2007	4.157	1.003	0.770	1.003	1.300	0.706
2008	2.588	0.814	0.637	0.814	1.032	0.573
2009	2.284	0.879	0.692	0.879	1.106	0.618
2010	2.112	0.652	0.514	0.652	0.816	0.458
2011	2.237	0.971	0.746	0.971	1.255	0.683
2012	2.752	1.210	0.942	1.210	1.545	0.851
2013	2.507	1.735	1.224	1.735	2.468	1.220
2014	2.214	1.282	0.851	1.282	1.935	0.902

Appendix Table 2. Nominal and standardize CPUE in weight (kg of fish per 1000 hooks) in real scale and relative scale in which the average from 1970 to 2014 is 1.0. The point in real scale is calculated by exp (lsmean)-mean/10, the upper is calculated as exp (lsmean+1.96*standard error)-mean/10, the lower is calculated by exp (lsmean-1.96 standard error)-mean/10. The lsmean is least square means of "year effect". These values are conditioned by the area effect as mentioned in the text.

CPUE in weight

Year	nominal		standardized			
	real scale	relative scale	real scale			relative scale
			upper	point	lower	
1965						
1966						
1967						
1968						
1969						
1970	307.819	3.140	97.278	76.631	60.068	1.647
1971	252.388	2.574	80.593	64.820	51.848	1.393
1972	183.269	1.869	115.907	89.288	68.373	1.919
1973	155.919	1.590	86.348	64.050	46.998	1.377
1974	202.731	2.068	132.538	90.195	61.022	1.939
1975	130.055	1.327	74.613	59.142	46.550	1.271
1976	169.083	1.725	78.833	59.666	44.808	1.282
1977	96.265	0.982	65.581	48.699	35.662	1.047
1978	110.820	1.130	94.297	71.819	54.255	1.544
1979	87.784	0.895	122.426	93.624	71.160	2.012
1980	79.946	0.815	65.507	52.772	42.282	1.134
1981	93.110	0.950	86.982	72.477	60.190	1.558
1982	101.498	1.035	73.240	60.220	49.404	1.294
1983	68.514	0.699	76.194	58.666	44.809	1.261
1984	92.550	0.944	74.807	60.089	48.090	1.292
1985	99.045	1.010	49.823	40.782	33.231	0.877
1986	69.855	0.712	64.808	51.290	40.335	1.102
1987	92.243	0.941	67.307	54.183	43.401	1.165
1988	94.810	0.967	67.163	54.872	44.670	1.179
1989	88.532	0.903	50.564	42.479	35.551	0.913

Appendix Table 2 (continue)

	CPUE in weight					
Year	nominal		standardized			
	real scale	relative scale	real scale			relative scale
			upper	point	lower	
1990	55.380	0.816	68.110	55.380	44.896	1.190
1991	42.213	0.607	52.384	42.213	33.876	0.907
1992	48.529	0.487	61.515	48.529	38.097	1.043
1993	23.469	0.451	29.805	23.469	18.318	0.504
1994	39.597	0.584	51.375	39.597	30.505	0.851
1995	28.160	0.732	33.881	28.160	23.275	0.605
1996	30.093	0.665	35.599	30.093	25.298	0.647
1997	22.864	0.538	27.380	22.864	18.930	0.491
1998	26.113	0.769	30.865	26.113	21.942	0.561
1999	27.459	0.589	33.005	27.459	22.673	0.590
2000	29.676	0.599	35.081	29.676	24.952	0.638
2001	20.315	0.508	24.836	20.315	16.430	0.437
2002	20.259	0.461	25.161	20.259	16.090	0.435
2003	23.795	0.504	28.640	23.795	19.587	0.511
2004	31.184	0.923	36.960	31.184	26.153	0.670
2005	23.351	0.757	28.313	23.351	19.093	0.502
2006	31.338	0.809	37.645	31.338	25.915	0.674
2007	36.516	1.533	47.354	36.516	28.063	0.785
2008	32.298	1.000	41.001	32.298	25.265	0.694
2009	32.172	0.876	40.514	32.172	25.339	0.691
2010	24.081	0.741	30.252	24.081	18.941	0.518
2011	34.040	0.845	44.241	34.040	25.995	0.732
2012	37.941	0.902	48.757	37.941	29.339	0.815
2013	58.224	1.071	82.546	58.224	41.284	1.251
2014	48.829	0.952	73.976	48.829	32.405	1.050