CPUE standardization of striped marlin (*Tetrapturus audax*) caught by Taiwanese longline fishery in the Indian Ocean

Sheng-Ping Wang

Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, Keelung, Taiwan.

ABSTRACT

In this study, the delta-gamma general linear models with the targeting effect derived from principle component analysis were used to conduct the CPUE standardization of striped marlin caught by the Taiwanese longline fishery in the Indian Ocean for 1979-2016. The trends of CPUE series were obviously different for northern and southern Indian Ocean, while the area-aggregated CPUE series revealed a decreasing trend since 1980s and slightly increased in recent years.

1. INTRODUCTION

Striped marlin are largely considered to be a non-target species of industrial fisheries. Longlines account for around 69% of total catches in the Indian Ocean, followed by gillnets (24%), with remaining catches recorded under troll and handlines. In recent years, the catches of striped marlin were mainly made by Indonesia (drifting longline and coastal longline, 36%), Taiwan (longline, 24%), Iran (gillnet, 14%), and Pakistan (gillnet, 8%). The catches reported under longlines are highly variable, with lower catch levels between 2009 and 2011 largely due to declining catches reported by Taiwan, deep-freezing and fresh-tuna longliners. Catches of striped marlin have since increased in 2012 and 2013, as longline vessels have resumed operations in the north-west Indian Ocean (IOTC, 2016).

Fig. 1 shows the historical catches by species and catch proportion of striped marlin based on the logbook data of Taiwanese fishery. The annual proportion of striped marlin was generally less 3% of total catches except for the years before the late 1980s, and revealed a decreasing trend since 1980s. Fig. 2 shows the nominal CPUE distribution of striped marlin of Taiwanese fleet. High values of CPUE occurred in tropical and subtropical areas in the 1980s and 1990s; CPUE substantially decreased since 2000s and high CPUE occurred in the offshore area in the norther area in 2000s and in the western area in 2010s.

Because striped marlin was bycatch species of Taiwanese lognline fishery, large amount of zero-catches was recorded in the operational catch and effort data sets of Taiwanese longline fishery. In recent decades, the annual proportions of zero-catch were about 70-90% of total data sets. In previous study (Wang, 2015), the delta-lognormal GLM (Pennington, 1983; Lo et. al., 1992; Pennington, 1996) was applied to conduct CPUE standardization of striped marlin in the Indian Ocean but the model with lognormal assumption for the residuals might not appropriate for fitting to the data. Therefore, a delta-gamma GLM was adopted in this study. The results of principle component analysis (PCA) based on the data sets in relation to species composition of the catches were also incorporated into CPUE standardization as an effect related to fishing operation (see Wang (2017) for the details).

2. MATERIALS AND METHODS

2.1. Catch and Effort data

In this study, daily operational catch and effort data (logbook) with 5x5 degree longitude and latitude grid for Taiwanese longline fishery during 1980-2016 were provided by Oversea Fisheries Development Council of Taiwan (OFDC). It should be noted that the data in 2016 is preliminary.

The data of number of hooks between float (NHBF) were available since 1994 and the collection of NHBF data were more complete since 1995. Therefore, the data of NHBF may not be applicable to conduct the long-term CPUE standardization for fishes caught by Taiwanese longline fishery in the Indian Ocean.

2.2. CPUE Standardization

A gamma-lognormal GLM was applied to standardize the CPUE. As the approach of Wang (2017), the models were simply conducted with the main effects considered in this analysis were year, month, 5x5 longitude-latitude grid, and the effects related to the fishing configurations (principal component scores), while interactions between main effects were not incorporated into the models. In addition, CPUE standardizations were also performed by four fishing areas separately based on the areas defined by Wang and Nishida (2011) (Fig. 3). The gamma and delta models were conducted as follows:

Gamma model for CPUE of positive catch:

$$\log(CPUE) = \mu + Y + M + G + T + \varepsilon^{\text{gamma}}$$

Delta model for presence and absence of catch:

$$PA = \mu + Y + M + G + T + \varepsilon^{del}$$

where	*CPUE*	is the nominal CPUE of positive catch of striped marlin (catch in number/1,000 hooks),
	PA	is the nominal presence and absence of catch,
	μ	is the intercept,
	Y	is the effect of year,
	M	is the effect of month,
	G	is the effect of 5x5 longitude-latitude grid,
	T	is the effect of targeting (principal component scores (PC_i) derived from the ith principle component),
	ε^{gamma}	is the error term, ε^{gamma} ~ Gamma distribution with log link function,
	ε^{del}	is the error term, ε^{del} ~ Binomial distribution.

The models performed by stepwise search ("both" direction, i.e. "backward" and "forward") and selected based on the values of the coefficient of determination (R^2), Akaike information criterion (AIC) and Bayesian information criterion (BIC). The standardized CPUE were calculated based on the estimates of least square means of the interaction between the effects of year and area.

The area-specific standardized CPUE trends were estimated based on the exponentiations of the adjust means (least square means) of the year effects (Butterworth, 1996; Maunder and Punt, 2004). The standardized relative abundance index was calculated by the product of the standardized CPUE of positive catches and the standardized probability of positive catches:

$$index = e^{\log(CPUE)} \times \left(\frac{e^{\tilde{P}}}{1 + e^{\tilde{P}}} \right)$$

where	*CPUE*	is the adjust means (least square means) of the year effect of the lognormal model,
	$\tilde{P}$	is the adjust means (least square means) of the year effect of the delta model.

2.3. Adjustment by area size

The estimation of annual nominal and standardized CPUE was calculated from the weighted average of the area indices (Punt et al., 2000).

$$U_y = \sum_a S_a U_{y,a}$$

Where U_y is CPUE for year y,
$U_{y,a}$ is CPUE for year y and area a,
S_a is the relative size of the area a to the four new areas.

The relative sizes of nine IOTC statistics areas for swordfish in the Indian Ocean (Nishida and Wang et al., 2006) were used to be aggregated into four areas used in this study.

Area	NW	NE	SW	SE
Relative area size	0.2478	0.2577	0.1638	0.3307

3. RESULTS AND DISCUSSION

Based on the model selections for the gamma models incorporated *PCi* (principle component scores) as effects of targeting, all of main effects were statistically significant and remained in the models, except for the effect of month for the model in the area SE. The selected gamma models were:

Area NE, NW and SW: $CPUE = \mu + Y + M + G + PC1 + PC2 + PC3$

Area SE: $CPUE = \mu + Y + G + PC1 + PC2 + PC3$

The ANOVA tables for selected gamma models are shown in the Table 1. The results indicate that the effects of *PC3* was the most explanatory effect for the models in areas NE, NW and SW, while the effects of *PC1* , *PC2* and *PC3* provided significant contributions to explanation of variance for the model in the area SE. Thus, the targeting of fishing operation might influence the CPUE derived from the positive catch of striped marlin.

For the delta models, all of the effects were statistically significant and remained in the model, except for the effect of *PC3* for the model in the area SW. The selected delta model was:

$$\text{Area NE, NW and SE:}\quad PA = \mu + Y + M + G + PC1 + PC2 + PC3$$

$$\text{Area SW:}\quad PA = \mu + Y + G + M + PC1 + PC2$$

The ANOVA tables for selected delta models are shown in the Table 2. Except for the effect of year, the most explanatory effect for the models was the effect of 5x5 grid and the secondary explanatory effect was *PC3*. The results indicated that the catch probability of striped marlin in the Indian Ocean might be mainly influenced by spatial effect.

The area-specific standardized CPUE series are shown in Fig. 4. The trends of CPUE series in the northern areas (NW and NE) reveal similar trends and they substantially decreased since 1980s although CPUE in NW increased in recent years. In the southern areas (SW and SE), the CPUE fluctuated before the early 2000s, substantially decreased until the late 2000s, and slightly increased in recent years. The area-aggregated CPUE series was similar to the CPUE series in the northern areas, which revealed a decreasing trend since 1980s and slightly increased in recent years (Fig. 5).

REFERENCE

Butterworth, D.S., 1996. A possible alternative approach for generalized linear model analysis of tuna CPUE data. ICCAT Col. Vol. Sci. Pap., 45: 123-124.

IOTC, 2016. Report of the 14th Session of the IOTC Working Party on Billfish. IOTC-2016-WPB14-R[E].

Lo, N.C.H., Jacobson, L.D., Squire, J.L., 1992. Indices of relative abundance from fish spotter data based on delta-lognormal models. Can. J. Fish. Aquat. Sci., 49: 2515-2526.

Maunder, N.M., Punt, A.E., 2004. Standardizing catch and effort data: a review of recent approaches. Fish. Res., 70: 141-159.

Pennington, M., 1983. Efficient estimation of abundance, for fish and plankton surveys. Biometrics, 39: 281-286.

Pennington, M., 1996. Estimating the mean and variance from highly skewed marine data. Can. J. Fish. Aquat. Sci., 94: 498-505.

Punt, A. E., Walker, T.I., Taylor, B.L., Pribac, F., 2000. Standardization of catch and effort data in a spatially-structured shark fishery. Fish. Res. 45: 129-145.

Wang, S.P., 2015. CPUE standardization of striped marlin (*Kajikia audax*) caught by Taiwanese longline fishery in the Indian Ocean using targeting effect derived from cluster and principle component analyses. IOTC–2015–WPB13–31 Rev_1.

Wang, S.P., 2017. CPUE standardization of swordfish (*Xiphias gladius*) caught by Taiwanese longline fishery in the Indian Ocean. IOTC–2017–WPB15–17.

Wang, S.P., Nishida, T., 2011. CPUE standardization of swordfish (*Xiphias gladius*) caught by Taiwanese longline fishery in the Indian Ocean. IOTC-2011-WPB09-12.

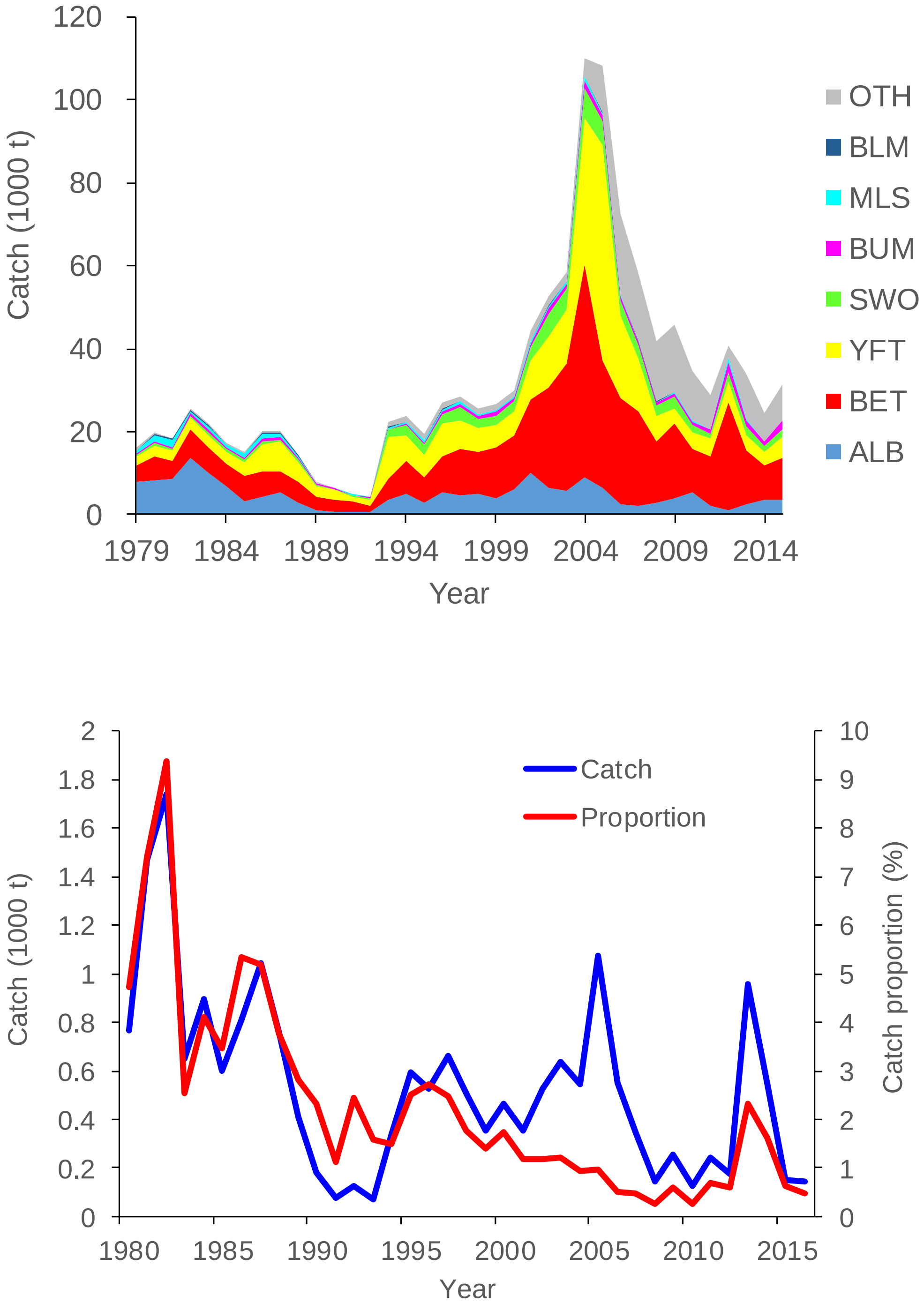


Fig. 1. Annual catches by species (upper panel) and catch of striped marlin (lower panel) caught by Taiwanese longline fishery in the Indian Ocean.

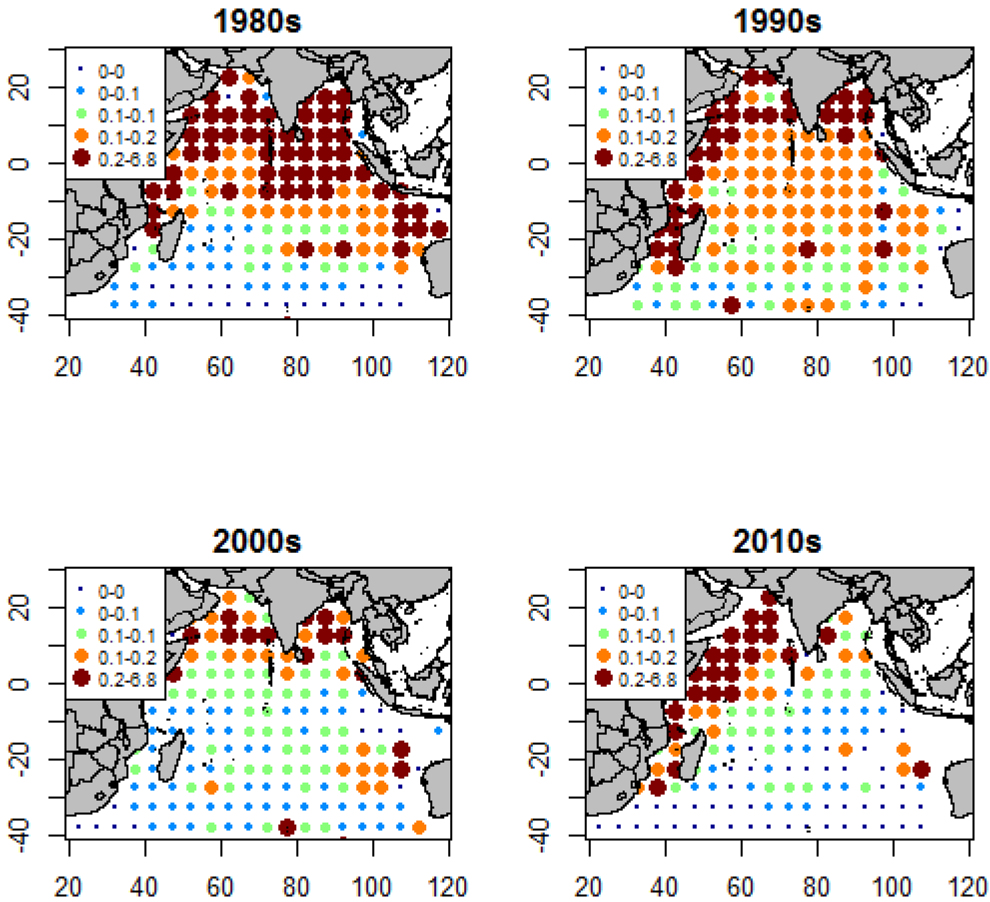


Fig. 2. Nominal CPUE distributions for striped marlin caught by Taiwanese longline fishery in the Indian Ocean.

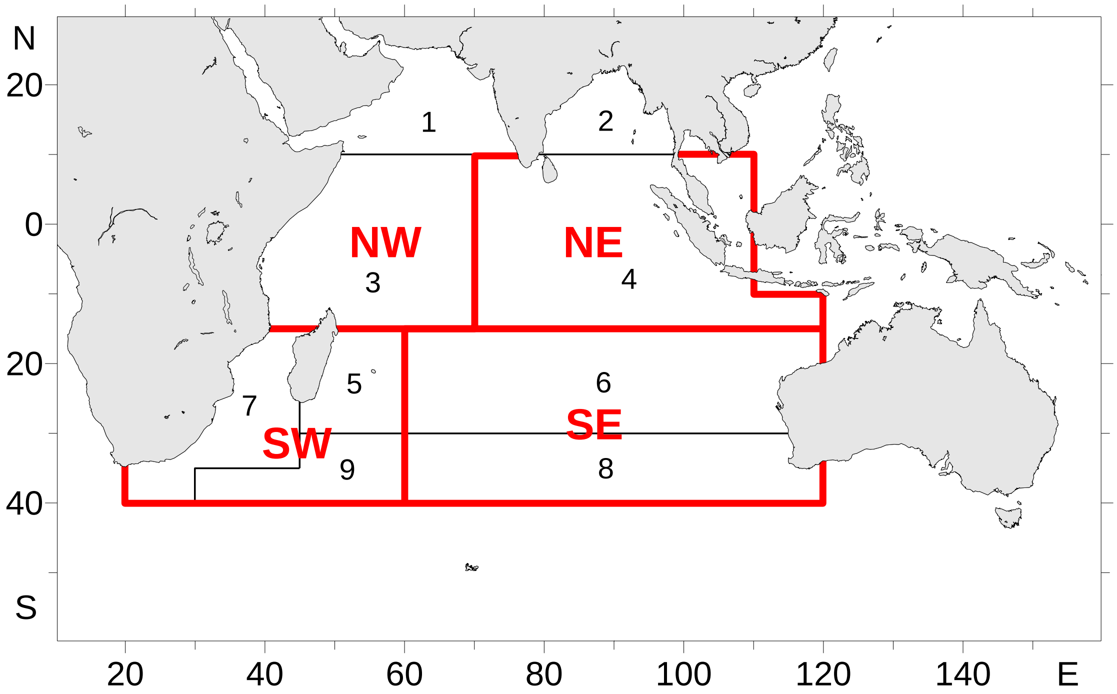


Fig. 3. Area stratification for swordfish in the Indian Ocean.

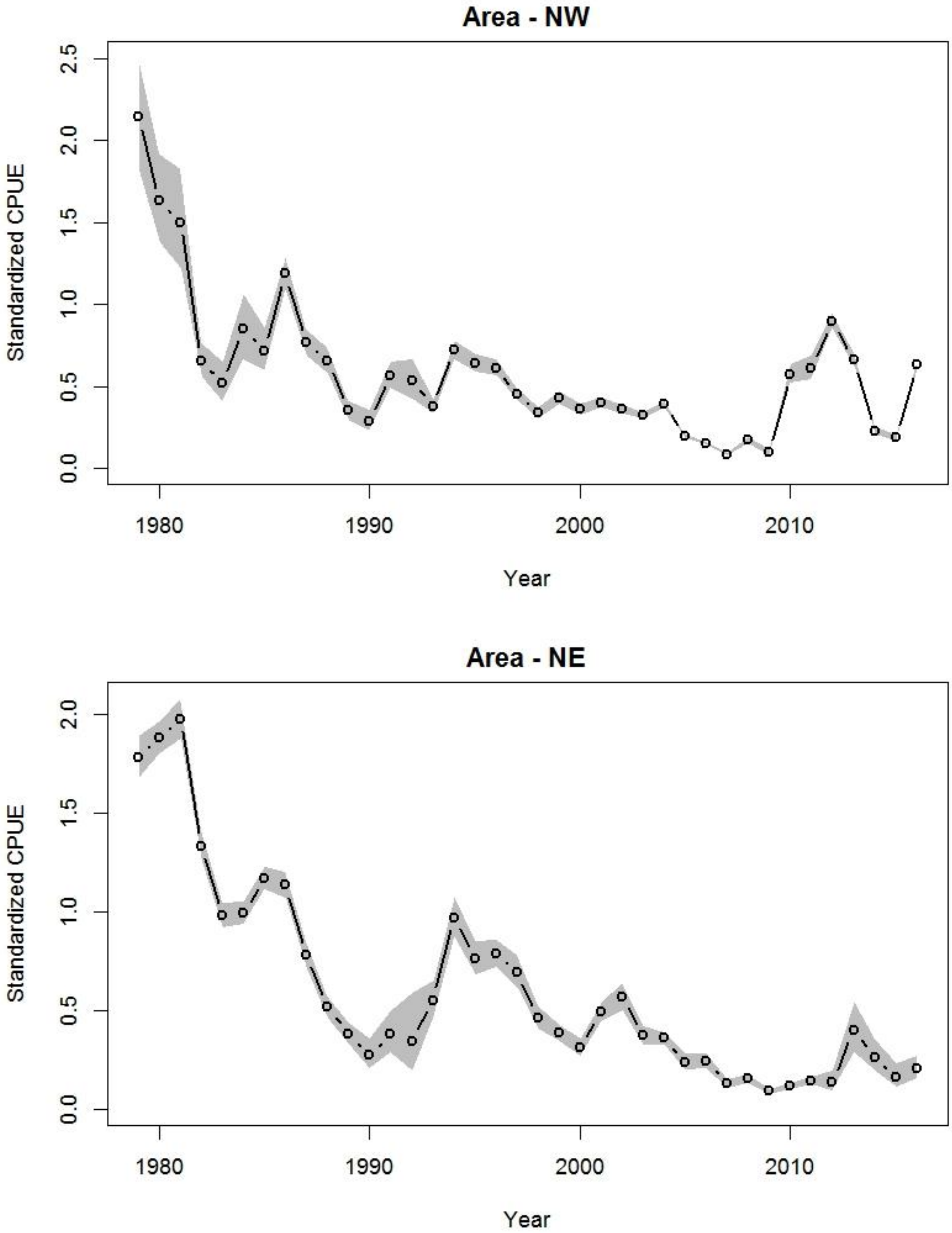
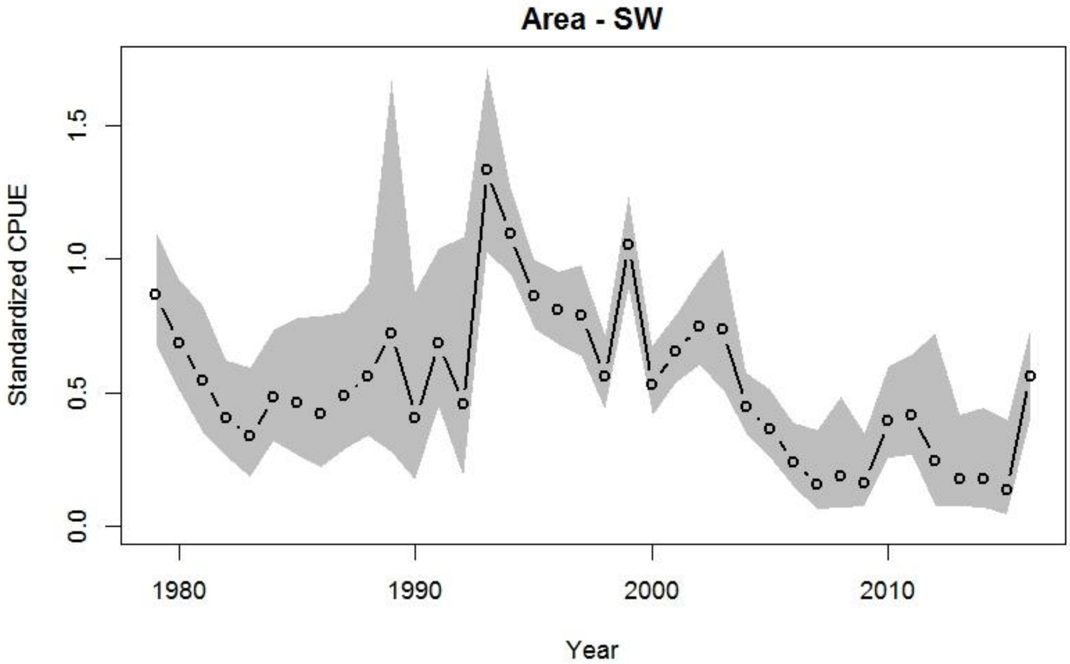


Fig. 4. Area-specific standardized (lines) CPUE with 95% confidence interval (shaded areas) for striped marlin of Taiwanese longline fishery in the Indian Ocean. CPUEs were scaled by the averaged value for each series.



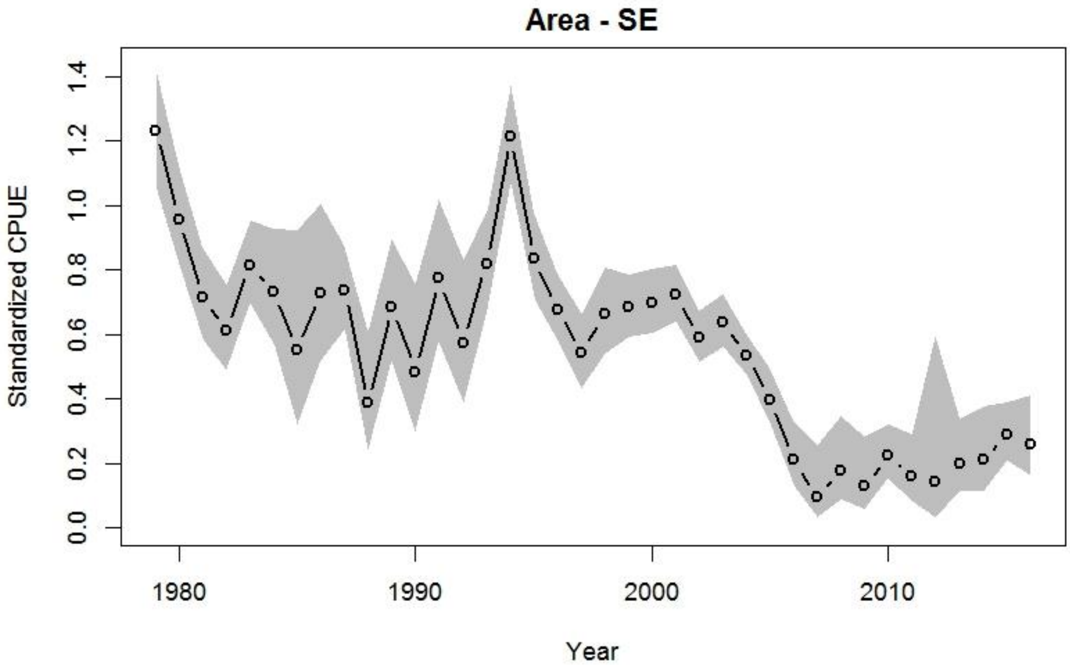


Fig. 4. (Continued).

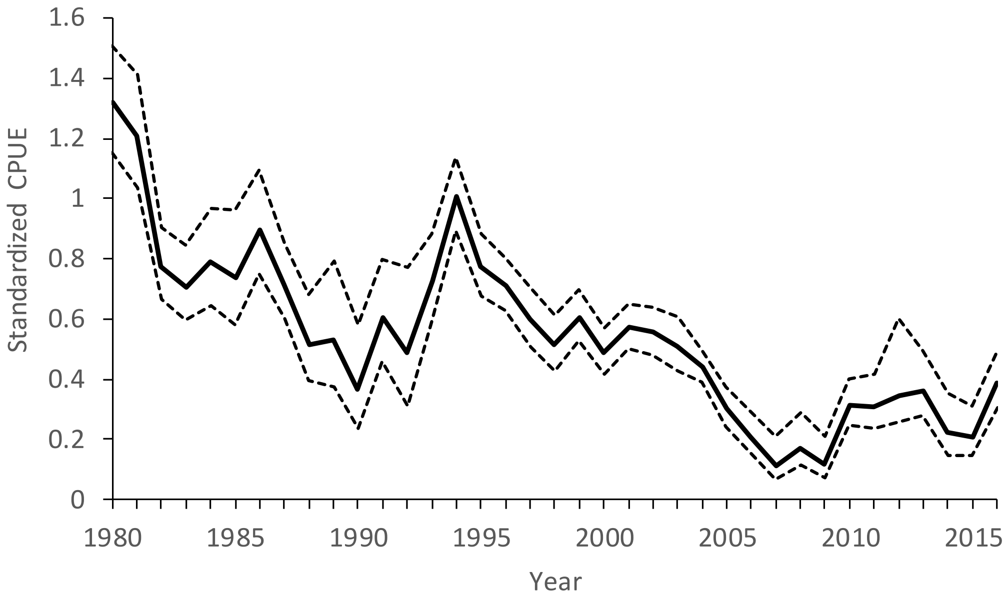


Fig. 5. Area-aggregated standardized (line) CPUE with 95% confidence interval (shaded area) for striped marlin of Taiwanese longline fishery in the Indian Ocean. CPUEs were scaled by the averaged value for each series.

Table 1. The ANOVA tables for selected gamma models.

Area NW

	SS	Df	F	Pr(>F)
Y	5773	37	175.325	< 2.2e-16 ***
M	524	11	53.544	< 2.2e-16 ***
G	2551	46	62.329	< 2.2e-16 ***
PC1	151	1	169.669	< 2.2e-16 ***
PC2	47	1	53.289	2.90E-13 ***
PC3	1416	1	1591.360	< 2.2e-16 ***
Residuals	93623	105207		

Area NE

	SS	Df	F	Pr(>F)
Y	7443	37	348.931	< 2.2e-16 ***
M	548	11	86.456	< 2.2e-16 ***
G	1477	42	61.013	< 2.2e-16 ***
PC1	12	1	21.487	3.57E-06 ***
PC2	85	1	148.231	< 2.2e-16 ***
PC3	1586	1	2750.528	< 2.2e-16 ***
Residuals	37815	65592		

Area SW

	SS	Df	F	Pr(>F)
Y	331.2	37	8.992	< 2.2e-16 ***
M	42	11	3.839	1.53E-05 ***
G	576.6	29	19.972	< 2.2e-16 ***
PC1	7.3	1	7.320	0.006832 **
PC2	32.5	1	32.675	1.12E-08 ***
PC3	100	1	100.396	< 2.2e-16 ***
Residuals	9608.4	9651		

Area SE

	SS	Df	F	Pr(>F)
Y	648.6	37	34.374	< 2.2e-16 ***
G	144.6	53	5.348	< 2.2e-16 ***
PC1	75.2	1	147.539	< 2.2e-16 ***
PC2	46.3	1	90.876	< 2.2e-16 ***
PC3	64.4	1	126.265	< 2.2e-16 ***
Residuals	6679.9	13099		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 2. The ANOVA tables for selected delta models.

Area NW

	LR Chisq	Df	Pr(>Chisq)
Y	31592	37	< 2.2e-16 ***
M	2632.3	11	< 2.2e-16 ***
G	7003.7	49	< 2.2e-16 ***
PC1	14.8	1	0.0001214 ***
PC2	413.3	1	< 2.2e-16 ***
PC3	2420.4	1	< 2.2e-16 ***

Area NE

	LR Chisq	Df	Pr(>Chisq)
Y	37459	37	< 2.2e-16 ***
M	856	11	< 2.2e-16 ***
G	5103	42	< 2.2e-16 ***
PC1	106	1	< 2.2e-16 ***
PC2	362	1	< 2.2e-16 ***
PC3	4047	1	< 2.2e-16 ***

Area SW

	LR Chisq	Df	Pr(>Chisq)
Y	3535.3	37	< 2.2e-16 ***
M	357.9	11	< 2.2e-16 ***
G	1345.1	32	< 2.2e-16 ***
PC1	70	1	< 2.2e-16 ***
PC2	257	1	< 2.2e-16 ***

Area SE

	LR Chisq	Df	Pr(>Chisq)
Y	3038.51	37	< 2.2e-16 ***
M	801.77	11	< 2.2e-16 ***
G	2272.33	53	< 2.2e-16 ***
PC1	7.52	1	6.11E-03 **
PC2	306.96	1	< 2.2e-16 ***
PC3	224.73	1	< 2.2e-16 ***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1