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CPUE standardization of Indian Ocean swordfish from Taiwanese longline fishery for Data up to 2003

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INTRODUCTION

Taiwanese longline fishery in the Indian Ocean commenced in mid-1950s and targeted on yellowfin tuna in the beginning. Following the development of the fishery, two different operation patterns were currently established: the first targets on albacore for canning and the other on tropical tuna species (bigeye tuna and yellowfin tuna) for sashimi market. Since 1990s, however, swordfish has become a seasonal target species to some of the fleets, which have made the major portion (about 40-60%) of the overall catch in the Indian Ocean during recent decades.

Historically most of the swordfish catch in the Indian Ocean was made by lognline fisheries. Fig. 1 shows the historical catches of the major tunas and swordfish caught by Taiwanese longline fishery in the Indian Ocean.. Among the longline nations, Taiwan (seasonal targeting fishery) and Japan (bycatch fishery) have the longest period of catch data series. Besides, Taiwanese data are of importance due to its targeting feature and the high proportion to the total catch. Studies on CPUE standardization of Taiwanese data is thus important for understanding the stock status, but is not straightforward because the data have confounded with many factors, especially the target-shifting effect.

In this paper, the standardization of CPUE for swordfish caught by Taiwanese longline fisheries in the Indian Ocean is performed using generalized liner model (GLM) on the data series up to 2003.

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MATERIAL AND METHODS

The data

The Taiwanese catch and effort data are compiled from logbooks and start from 1967 to 2003. For 1967-1978, only aggregated $5^{\circ} \times 5^{\circ}$ square monthly data are available, and both original logbooks and aggregated data are available since 1979. In this paper, logbooks data including the basic information of fishing time, fishing area, hooks, catches and the information of numbers of hooks per basket are used to analyze the CPUE trends of swordfish. However, the data of numbers of hooks per basket are available for only years after 1995. The data were provided by the Overseas Fisheries Development Council of the Republic of China.

For the environmental data, Sea Surface Temperature (SST) is from the SAGE. For details of these data refer to Okamoto et al. (2001). In addition, the information of the Indian Oscillation Index (IOI) is provided by NRIFSF and refers to Nishida and Wang (2006) for the details.

For selection of sub areas (Fig. 2), the availability of catch and effort data are examined by areas for 1979-2003 (Fig. 3). Taiwanese swordfish catches were mainly made in area 3 and 7 after the late of 1980s. The catches in these two areas were much higher than other areas. For consistency between Taiwanese and Japanese analyses (Nishida and Wang, 2006), the data in sub area 3, 4, 6, 7 and 8 are used to perform GLM analyses.

The model

In this paper, GLM is used to model the logarithm of the nominal CPUE (defined as the number of fish per 1,000 hooks). The main effects considered in this analysis are year, quarter, area, target, SST, and IOI. The interactions for the main effects are also included into the model.

$$\log(CPUE + c) = \mu + Y + Q + A + T + SST + IOI + \text{Interactions} + \varepsilon$$

where *CPUE* is the nominal CPUE of swordfish,

c is the constant value (i.e. 10% of the average nominal CPUE),

μ	is the intercept,
Y	is the effect of year,
Q	is the effect of quarter,
A	is the effect of fishing area,
T	is the effect of target,
SST	is the effect of sea surface temperature,
IOI	is the effect of Indian Oscillation Index,
Interactions	is the interactions between main effects,
ε	is the error term, $\varepsilon \sim N(0, \sigma^2)$.

The quarters used in the model follows the definition in the 2004 WPB meeting, i.e. the first quarter is Jan-Mar, the second quarter is Apr-May, the third quarter is Jun-Sep and the forth quarter is Oct-Dec.

Due to insufficient information on gear configuration (e.g. hooks per basket), two indices are used to express the target effects:

Case 1: the quartile of catch composition of swordfish against the four main species (albacore, bigeye tuna, yellowfin tuna and swordfish);

Case 2: three categories of swordfish catch composition defined based on the information of hooks per basket (i.e. <8%, 8-15% and >15%) and this index has been used in the 2003 WPM meeting and 2004 WPB meeting (Chang and Wang, 2004).

Adjustment by area size

The estimation of annual standardized CPUE is calculated from the weighted average of the area indices (Change and Wang, 2004).

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

Where		
	U_y	is the standardized CPUE for year y,
	$U_{y,a}$	is the standardized CPUE for year y and area a,
	S_a	is the relative size of the area a to the overall studied area.

RESULTS AND DISCUSSION

For Case 1, the main effects of SST and IOI are excluded because they are not statistically significant based on the full model analysis. Thus the interactions related to these two effects also excluded from the model. The ANOVA table for Case 1 shows in Table 1 and the distribution of residuals shows in Fig. 4(A). The selected model of Case 1 is:

$$\log(CPUE + c) = \mu + Y + Q + A + T + Y * A + Q * A + Q * T + A * T + \varepsilon$$

For Case 2, the main effect of SST is still excluded from the model because it is still statistically insignificant but the effect of IOI is remained for this case. Other interactions excluded from the model because they are statistically insignificant or significant but negligible effects on the change of deviance. Table 2 and Fig. 4(B) show the ANOVA table and the distribution of residuals for Case 2. The selected model of Case 2 is:

$$\log(CPUE + c) = \mu + Y + Q + A + IOI + T + Y * A + Q * A + Q * IOI + A * T + IOI * T + \varepsilon$$

Fig. 5 shows the standardized CPUE for each area. In area 7, the standardized CPUE obtained for Case 1 represented a declining pattern during 1992-2000 and then slight increased thereafter. For Case 2, the standardized in area 7 revealed a continuous declining pattern after 1992. The patterns of standardized CPUE in area 7 are more consistent with the trend of Japanese analysis (Nishida and Wang, 2006). In area 3, however, the standardized CPUE were relatively stable for whole series and increased in the last few years, which were reverse to the CPUE trend in other areas.

The nominal CPUE and standardized CPUEs estimated from the Case 1 are shown in Fig. 6. The nominal CPUE slight increased before the late of 1980's, decreased in the early 1990s, then increased with fluctuating before 1997, dropped substantially during 1997-2001, and increased again thereafter. Before the late of 1980s, standardized CPUE represented a stable pattern instead of an increasing trend, revealed a slightly declining pattern during 1994 to 2000, then increased slightly, and decreased again in 2003. Fig. 7 shows the nominal CPUE and standardized CPUEs estimated from the Case 2. The results of Case 2 are very similar to those of Case 1.

In this paper, two methods are used to derive the effect of target and they did influence other effects used in the model. The environmental effect (IOI) is only incorporated in the model for Case 2. However, the final estimations of standardized CPUE have no obvious difference for these two cases except the estimations in area 7 which have different trends in last few years (Fig. 5). The area size and the catch of swordfish in area 7 are much less than area 3 where Taiwanese longline fishery made the most proportion of swordfish (Fig. 4). Thus the different estimations between these two cases might not lead to the large different explanation for the trend of abundance index of swordfish in the Indian Ocean. In addition, sexual dimorphism is a very important biological characteristic of swordfish and it reveled not only on the growth pattern but on the sex ratio and maturity. Therefore, the incorporation of sex effect is important and necessary for the further investigation of population status of swordfish in the Indian Ocean.

REFERENCE

Nishida, T., and S. P. Wang (2006). Standardization of swordfish (Xiphias gladius) CPUE of the Japanese tuna longline fisheries in the Indian Ocean. IOTC-WPB-2006- .

Okamoto, H., Miyabe, N. and Matsumoto. (2001). GLM analyses for standardization of Japanese longline CPUE for bigeye tuna in the Indian Ocean. IOTC/WPTT/01/21, 38p.-377

Table 1. ANOVA table of the selected model for Case 1.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	163	63635.52795	390.40201	1931.15	<.0001
Error	51650	10441.58476	0.20216		
Corrected Total	51813	74077.11272			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.859044	-53.52608	0.449623	-0.840006

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Y	24	1241.23780	51.71824	255.83	<.0001
Q	3	119.58648	39.86216	197.18	<.0001
A	4	1927.94291	481.98573	2384.17	<.0001
Target_p_4q	3	59912.14018	19970.71339	98786.5	<.0001
Y*A	96	201.47811	2.09873	10.38	<.0001
Q*A	12	43.26731	3.60561	17.84	<.0001
Q*Target_p_4q	9	9.54390	1.06043	5.25	<.0001
A*Target_p_4q	12	180.33125	15.02760	74.34	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	24	194.86628	8.11943	40.16	<.0001
Q	3	26.93424	8.97808	44.41	<.0001
A	4	105.50655	26.37664	130.47	<.0001
Target_p_4q	3	28945.76699	9648.58900	47727.4	<.0001
Y*A	96	207.93011	2.16594	10.71	<.0001
Q*A	12	35.23045	2.93587	14.52	<.0001
Q*Target_p_4q	9	7.51025	0.83447	4.13	<.0001
A*Target_p_4q	12	180.33125	15.02760	74.34	<.0001

Table 2. Table 1. ANOVA table of the selected model for Case 2.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	155	33477.43089	215.98343	274.81	<.0001
Error	51658	40599.68182	0.78593		
Corrected Total	51813	74077.11272			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.451927	-105.5383	0.886528	-0.840006

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Y	24	1241.23780	51.71824	65.80	<.0001
Q	3	119.58648	39.86216	50.72	<.0001
A	4	1927.94291	481.98573	613.27	<.0001
IOI	1	42.09614	42.09614	53.56	<.0001
Target_p_HPB	2	29268.04340	14634.02170	18620.0	<.0001
Y*A	96	371.82898	3.87322	4.93	<.0001
Q*A	12	143.06294	11.92191	15.17	<.0001
IOI*Q	3	15.84600	5.28200	6.72	0.0002
A*Target_p_HPB	8	289.07578	36.13447	45.98	<.0001
IOI*Target_p_HPB	2	58.71045	29.35522	37.35	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Y	24	142.43936	5.93497	7.55	<.0001
Q	3	120.58140	40.19380	51.14	<.0001
A	4	134.13050	33.53262	42.67	<.0001
IOI	1	38.68059	38.68059	49.22	<.0001
Target_p_HPB	2	11541.17989	5770.58995	7342.35	<.0001
Y*A	96	365.99826	3.81248	4.85	<.0001
Q*A	12	131.47154	10.95596	13.94	<.0001
IOI*Q	3	16.09464	5.36488	6.83	0.0001
A*Target_p_HPB	8	277.60181	34.70023	44.15	<.0001
IOI*Target_p_HPB	2	58.71045	29.35522	37.35	<.0001

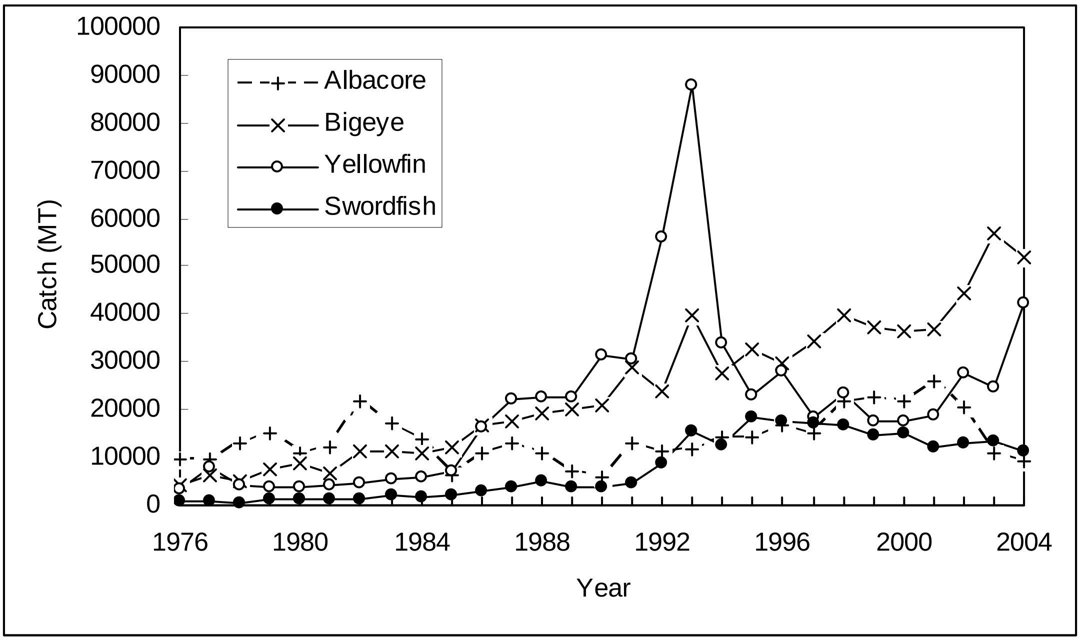


Fig. 1. Annual catches of the major tunas and swordfish in the Indian Ocean by Taiwanese longline fishery, 1976-2004 (the data in 2004 are preliminary).

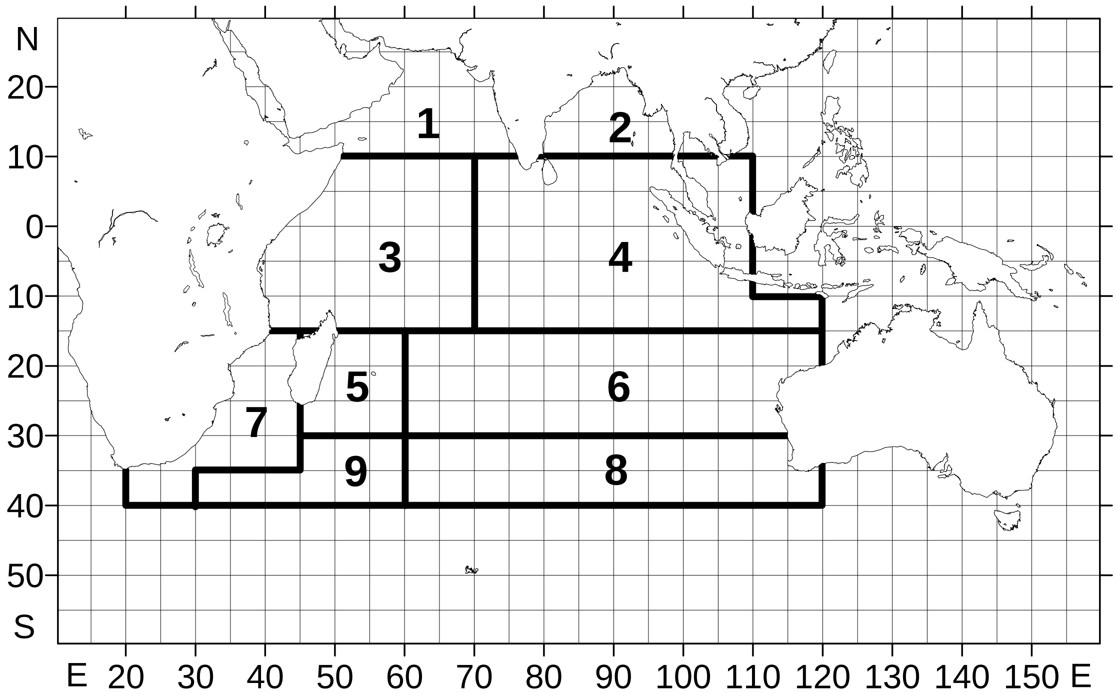


Fig. 2. Area stratification used fro the standardization of CPUE for swordfish in the Indian Ocean.

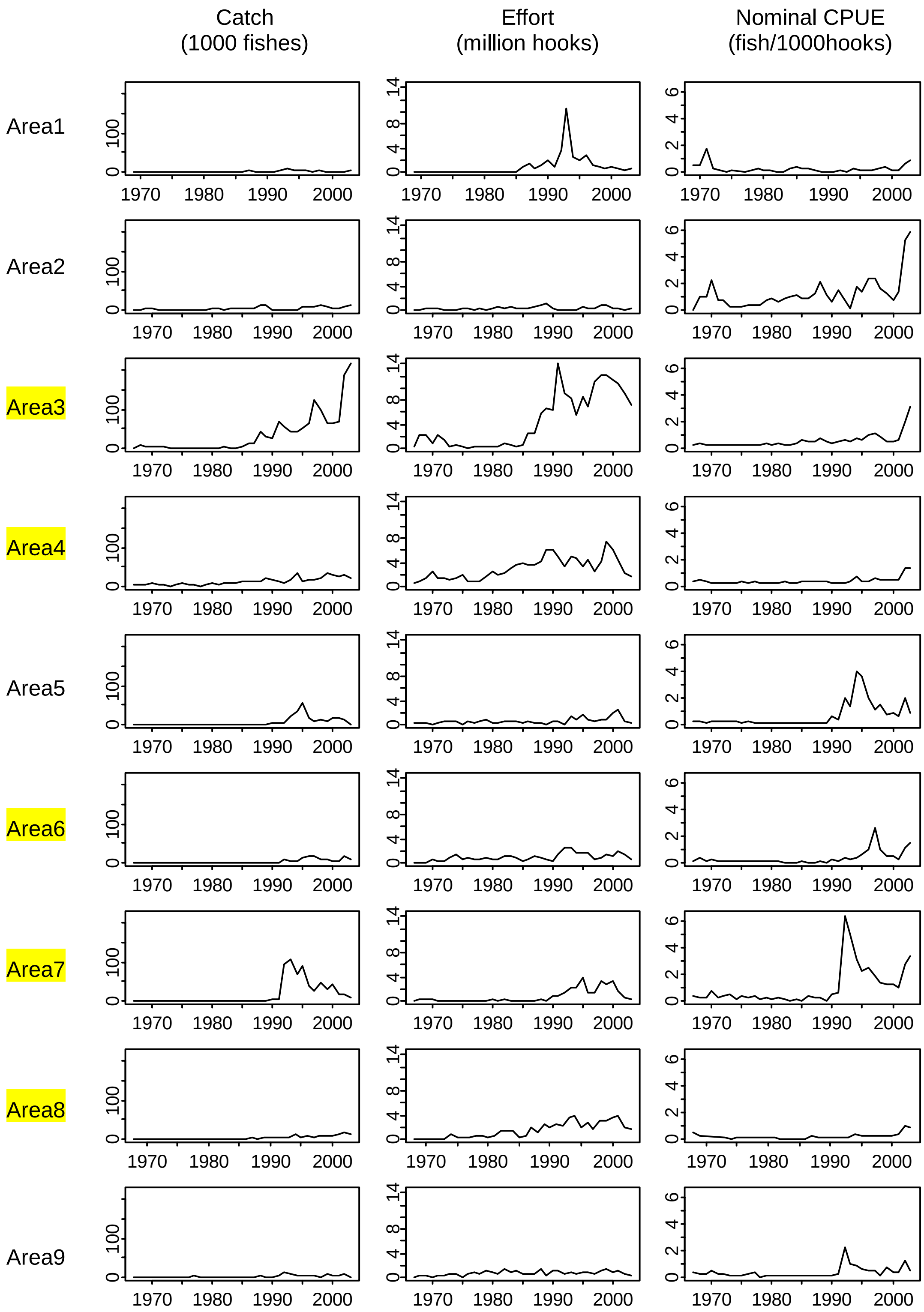


Fig. 3. The trends of catch of swordfish, effort and nominal CPUE by Taiwanese longline fishery for each sub-area (1979-2003).

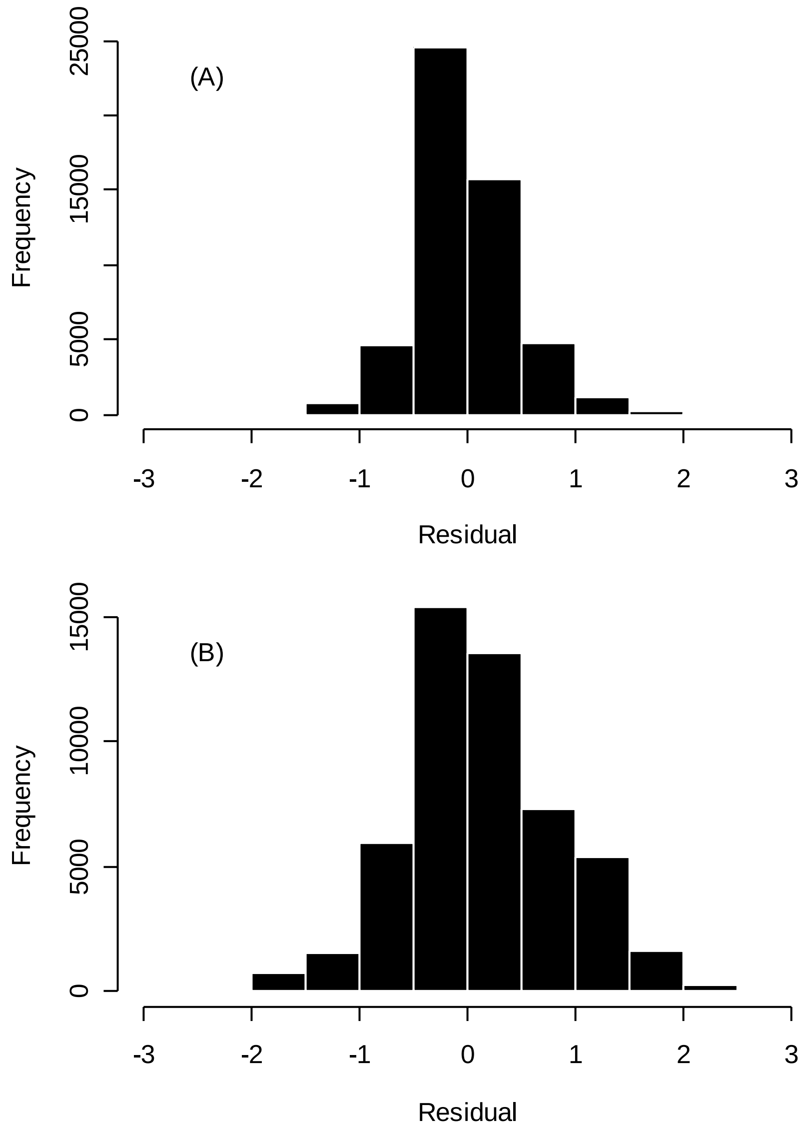


Fig. 4. Distributions of the residuals for the standardization models of Case 1 (A) and Case 2 (B).

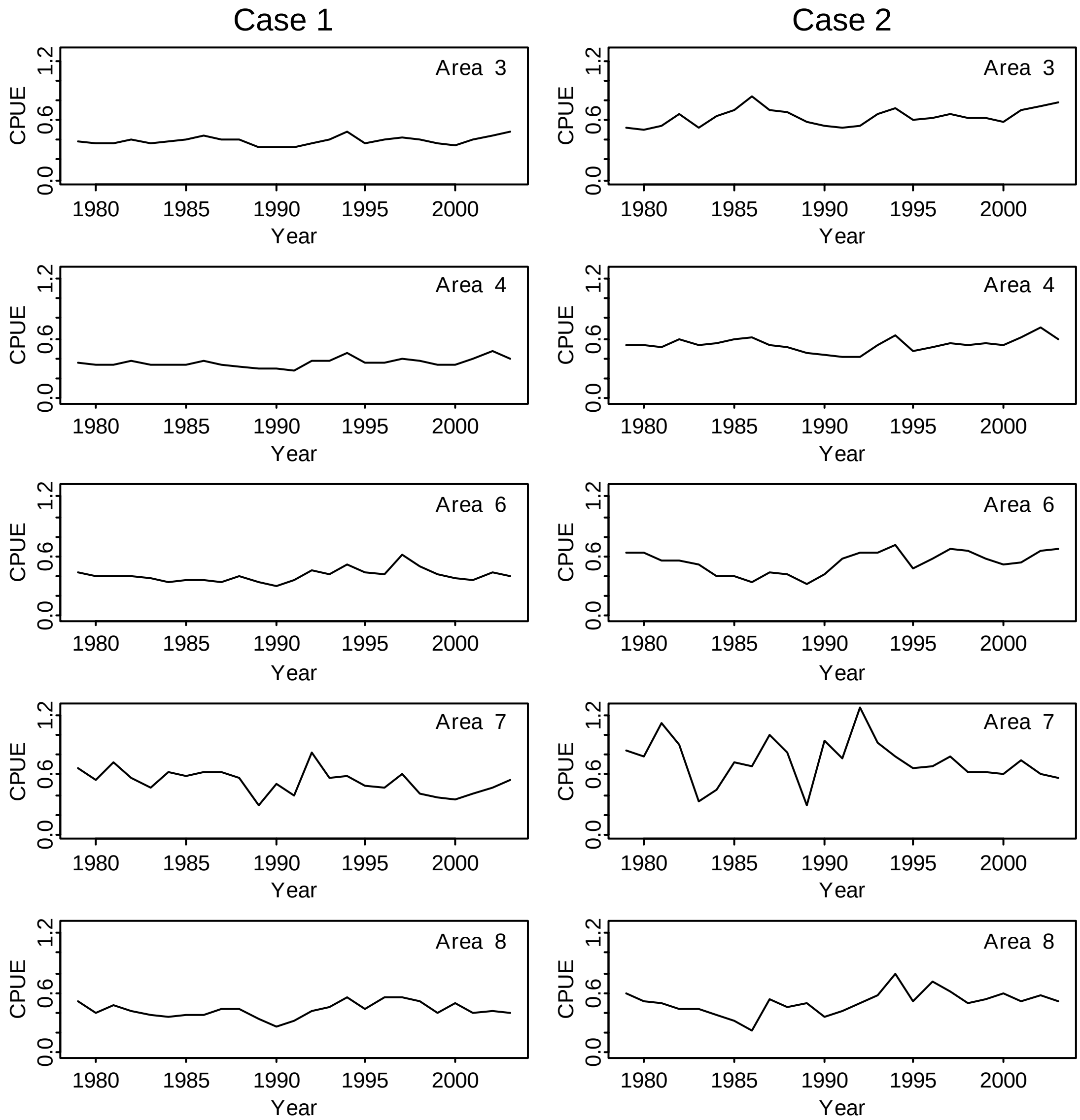
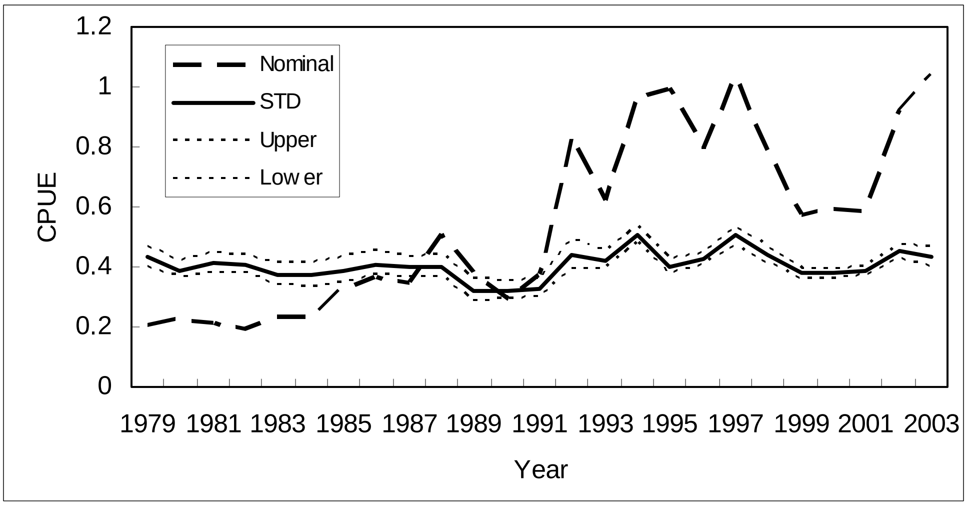


Fig. 5. The standardized CPUE of swordfish by Taiwanese longline fishery for each sub-area (1979-2003).

(A)



(B)

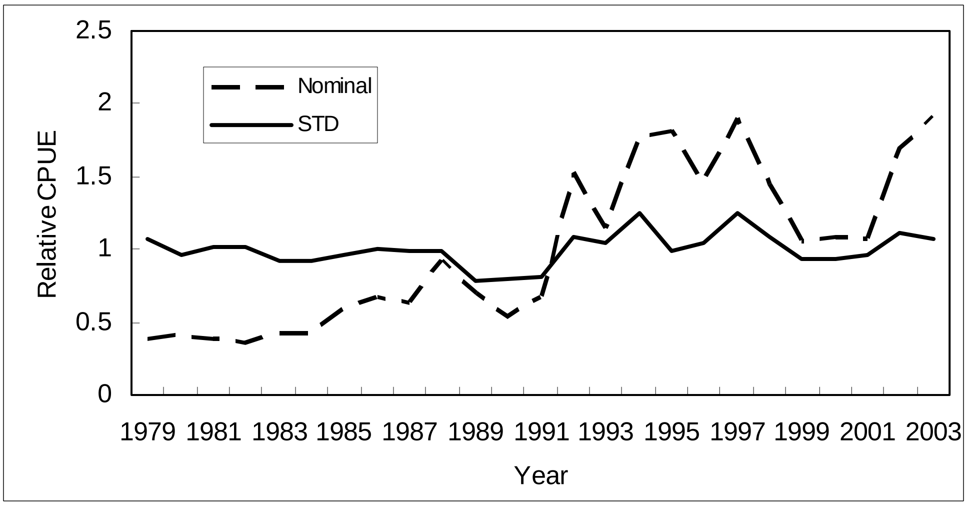
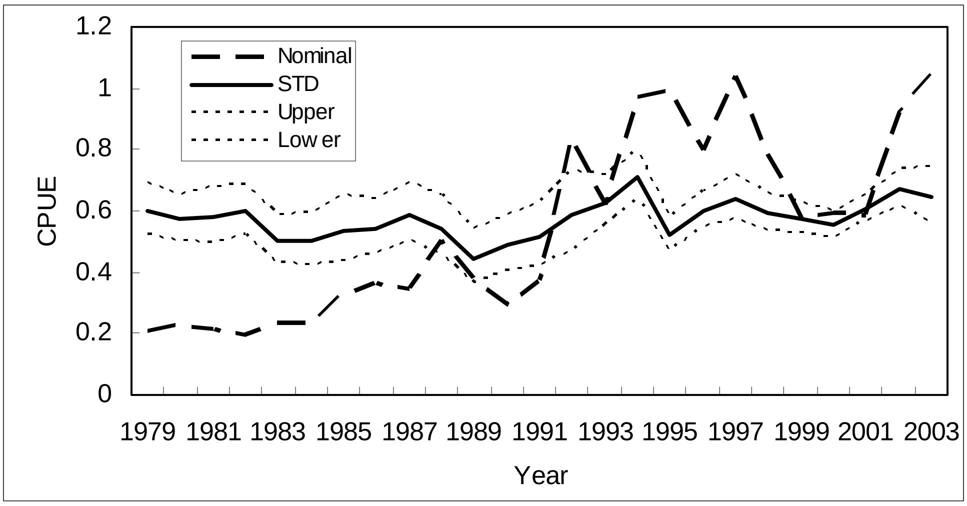


Fig. 6. The nominal and standardized CPUE of swordfish of Taiwanese longline fishery (1979-2003) from Case 1. The relative values are scaled to the average estimates.

(A)



(B)

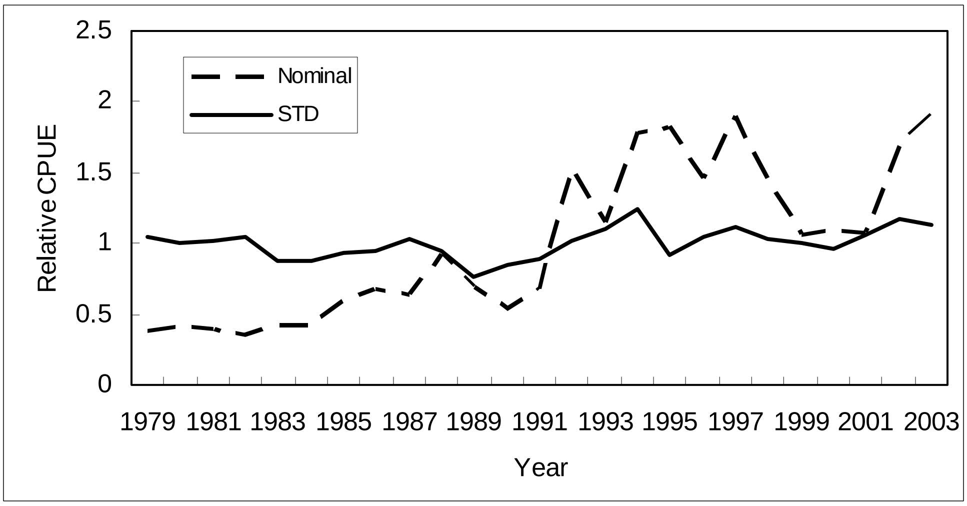


Fig. 7. The nominal and standardized CPUE of swordfish of Taiwanese longline fishery (1979-2003) from Case 2. The relative values are scaled to the average estimates.