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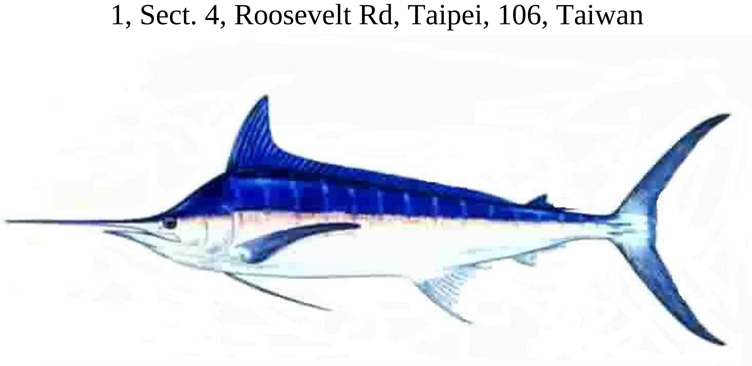

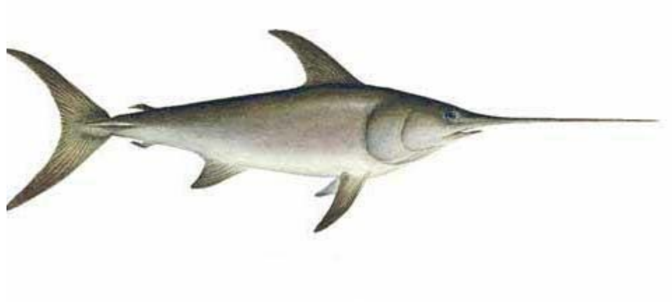

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Standardization of Taiwanese distant water tuna longline catch rates for swordfish in the North Pacific, 1995-2007, based on two stock structure scenarios[1]

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Abstract

Catch rates of swordfish for the Taiwanese tuna longline fishery in the North Pacific Ocean were standardized using a general linear model (GLM). The two stock structure scenarios suggested by Ichinokawa and Brodziak (2008) was assumed, which resulted in three final models. Each model includes the main variables year, quarter, area, hooks per basket (HPB), and all two-way interactions between quarter, area and HPB. Results of GLM analyses indicated an increase in standardized CPUEs during 2000 and 2001 for all three models, but a gradual decline after 2001 followed by an increase after 2005 for the single North Pacific stock and the SE Pacific stock, while only a gradual decline was observed for the NW Pacific stock after 2002. In general, the sub-area 2 (SE Pacific) had the highest CPUE, and sub-area 1 (NW Pacific) had the lowest CPUE.

Introduction

Taiwan's distant-water tuna longline fishery (hereafter referred to as longline fishery) has been operating in the Pacific Ocean since 1963. This fishery primarily targets albacore tuna, but significant numbers of yellowfin and bigeye tuna are landed (Sun and Yeh, 1999). Swordfish and other billfishes are incidental catches of this fishery. The purpose of this paper is to update the standardization of the catch rates (Yeh and Sun, 2008) for swordfish caught by Taiwan’s longline vessels in the North Pacific Ocean during the period of 1995 to 2007 using general linear model (GLM) procedures and assuming the two stock structure scenarios suggested by Ichinokawa and Brodziak (2008) and adopted by BWG (2008), and provide preliminary descriptions of the swordfish abundance trends in the North Pacific Ocean.

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Materials and Methods

Data on catch (number of fish) and effort (number of hooks) during the period 1995-2007 were provided by Oversea Fisheries Development Council (OFDC). Information on gear configuration (number of hooks per basket, HPB) is only available from daily logbooks data since 1995, and was also provided by OFDC. All data were aggregated into monthly 5^o x 5^o cells by year and HPB, and nominal CPUE (number of swordfish per 1000 hooks) values were estimated for each cell. The main variables chosen as input into the GLM analyses (Kimura 1981, Allen and Punsly 1984, Draper and Smith 1981) were year, quarter, area, and HPB. The following multiplicative model was applied to the data in this study:

$$\ln\,(CPUE_{ijkl} + 0.1) = \mu + Y_i + Q_j + A_k + HPB_l + (\,interaction\ terms) + \varepsilon_{ijkl}$$

where

ln	is the natural logarithm;
$CPUE_{ijkl}$	is the nominal catch rate (no. of fish / 1000 hooks) in year *i*, quarter *j*, area *k*, HPB *l*,
μ	is the overall mean;
Y_i	is year *i*;
Q_j	is quarter *j*;
A_k	is area *k*;
HPB_l	is number of hooks per basket *l*;
ε_{ijkl}	is the error term, NID $(0,\sigma^2)$.

The effect of gear configuration of HPB was categorized into the four classes of 1-9, 10-12, 13-14, and >=15, and quarter into the 4 classes of Jan-Mar (1^{st} quarter), Apr-Jun (2^{nd} quarter), Jul-Sep (3rd quarter) and Oct-Dec (4^{th} quarter). The areas used in this study are shown in Figure 1 for one single North Pacific stock scenario and Figure 2 for a two-stock scenario with a boundary between NW (sub-area 1) and SE (sub-area 2) as defined by Ichinokawa and Brodziak (2008).

Results and Discussion

The GLM analyses for the single North Pacific stock scenario (model 1) and the two-stock scenario (model 2 for NW area, and model 3 for SE area) yielded three final models. Each model includes the variables year, quarter, area, HPB, and the two way interactions between quarter, area, and HPB (Tables 1-3). The total numbers of observations for these three models were 6543, 3234 and 6933, respectively. Analyses of variance (ANOVA) showed that all the variables in each model were statistically significant (mostly <0.01). The fractions of sum of squares (i.e. R^2) explained by models 1, 2 and 3 are 0.23, 0.19, and 0.11, respectively. Frequency distributions of the standardized residuals for each of the models are normally distributed (Figure 3).

Figure 4 shows the estimates of annual standardized CPUE and nominal CPUE for the three models. Between 1995 and 1999, the standardized and nominal CPUEs for model 1 and model 2 are similar, ranging between 0.10 and 0.25 fish per thousand hooks, with no apparent trend, but for model 3 there is an apparent increasing and decreasing during this period.

After 1999, nominal CPUEs increased in 2000 and reached a high of approximately 0.9, 0.5 and 0.8 fish per thousand hooks in 2001 for models 1, 2 and 3, respectively. The standardized CPUEs showed a similar increase in 2000, but to much lower values. Nominal CPUEs sharply declined after 2001 followed by an increase after 2005 in models 1 and 3, while only a gradual decline was observed in model 2 after 2001. The standardized CPUEs showed similar declines after 2001 for models 1 and 3, and 2002 for model 2, but at much slower rates.

In general, the sub-area 2 (SE of Pacific) had the highest CPUE and sub-area 1 (NW of Pacific) had the lowest CPUE.

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Table 1. ANOVA table for swordfish CPUE in the North Pacific.

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL	6542	6714.5				
Year	12	817.9	6530	5896.5	85.2	<0.001
Quarter	3	12.9	6527	5883.6	5.4	0.001
Area	5	464.6	6522	5419.0	116.2	<0.001
HPB	3	59.2	6519	5359.8	24.7	<0.001
Quarter:Area	14	41.3	6505	5318.5	3.7	<0.001
Quarter:HPB	9	51.1	6496	5267.4	7.1	<0.001
Area:HPB	13	83.5	6483	5183.8	8.0	<0.001
R^2		0.23				

Table 2. ANOVA table for swordfish CPUE in the sub-area 1 of the Pacific Ocean.

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL	3233	2839.1				
Year	12	311.8	3221	2527.3	36.1	<0.001
Quarter	3	9.5	3218	2517.8	4.4	0.004
Area	4	63.3	3214	2454.5	22.0	<0.001
HPB	3	61.0	3211	2393.5	28.2	<0.001
Quarter:Area	11	15.1	3200	2378.4	1.9	0.033
Quarter:HPB	9	35.6	3191	2342.8	5.5	<0.001
Area:HPB	10	54.0	3181	2288.8	7.5	<0.001
R^2		0.19				

Table 3. ANOVA table for swordfish CPUE in the sub-area 2 of the Pacific Ocean.

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)
NULL	6932	7283.1				
Year	12	254.2	6920	7028.9	22.5	<0.001
Quarter	3	38.1	6917	6990.9	13.5	0.001
Area	1	73.3	6916	6917.6	77.7	<0.001
HPB	3	347.8	6913	6569.8	123.0	<0.001
Quarter:Area	3	17.4	6910	6552.4	6.2	<0.001
Quarter:HPB	9	32.4	6901	6520.0	3.8	<0.001
Area:HPB	3	16.5	6898	6503.4	5.8	0.001
R^2		0.11				

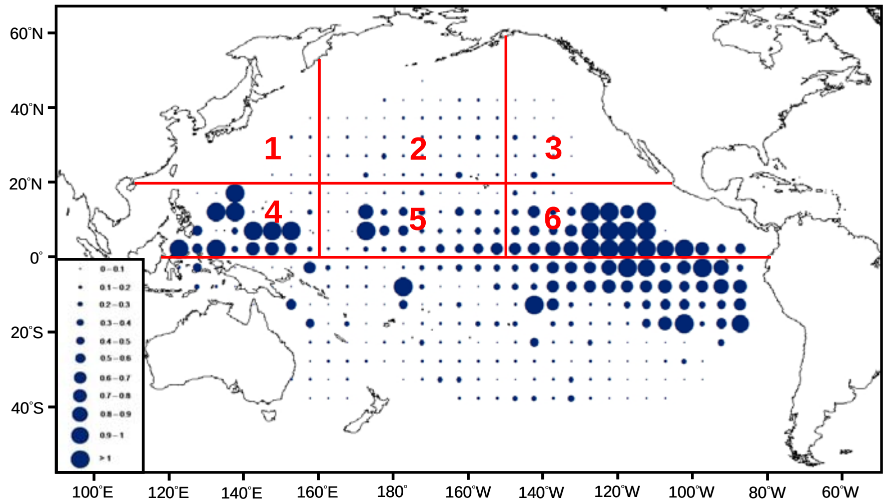

Fig. 1. The area stratification for the North Pacific Ocean for standardizing CPUE of swordfish in the Taiwanese longline fisheries.

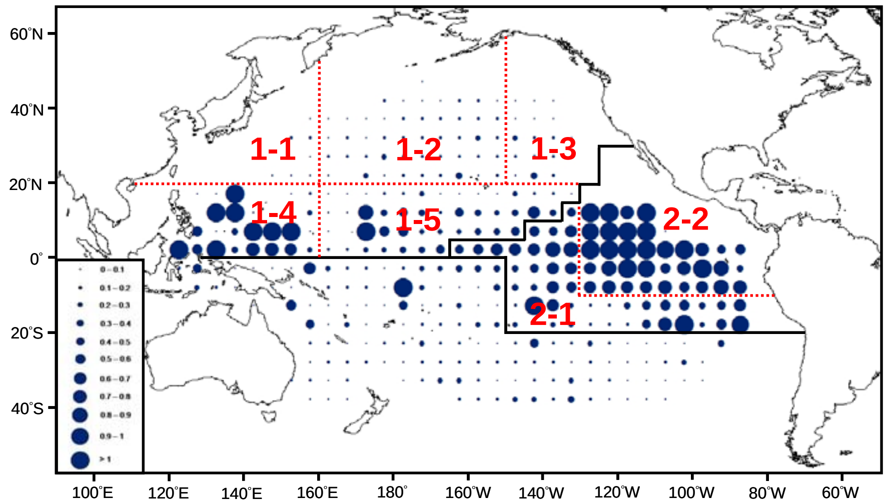

Fig. 2. The area stratification for sub-areas 1 and 2 of the Pacific Ocean for standardizing CPUE of swordfish in the Taiwanese longline fisheries.

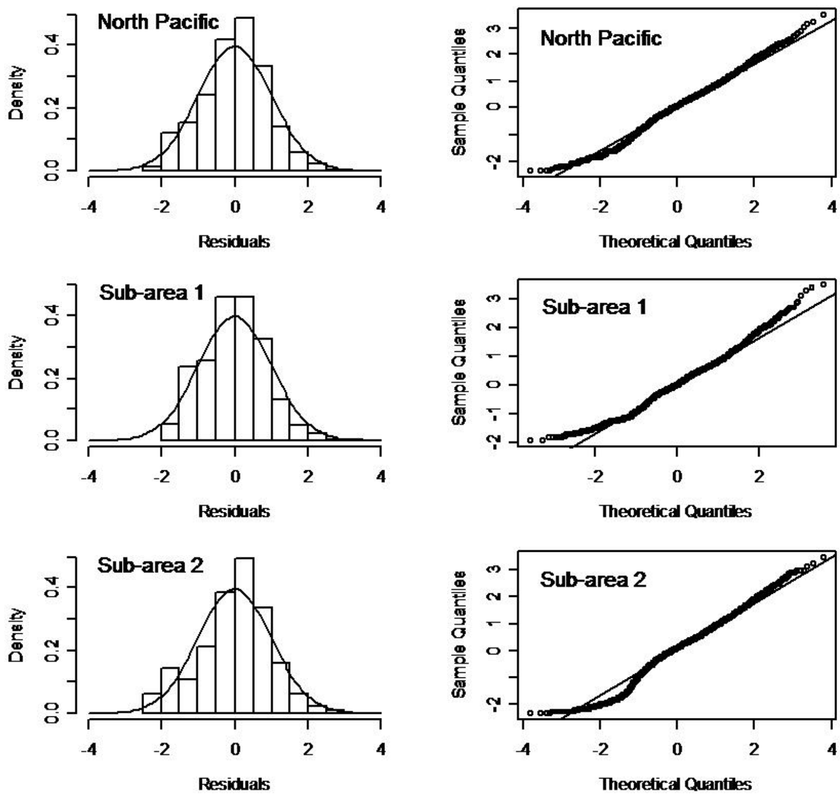

Fig. 3. The diagnostic plots (residual distribution and Q-Q plot) of GLM models for standardizing CPUE of swordfish in the Taiwanese longline fisheries.

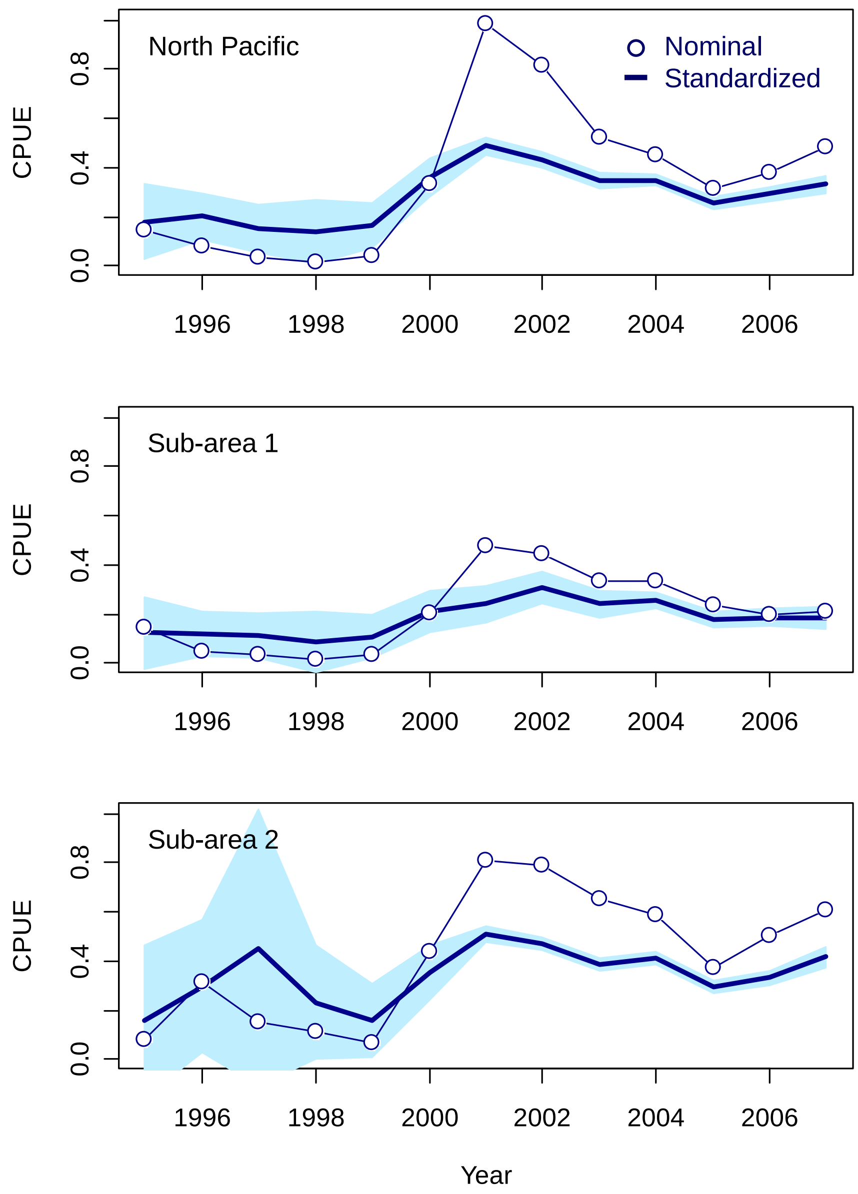

Fig. 4. The nominal (points) and standardized (lines) CPUE (number / 1000 hooks) of swordfish in the Taiwanese longline fisheries for 1995-2007. The shadows indicate the pointwise standard errors for the standardized CPUE of swordfish.