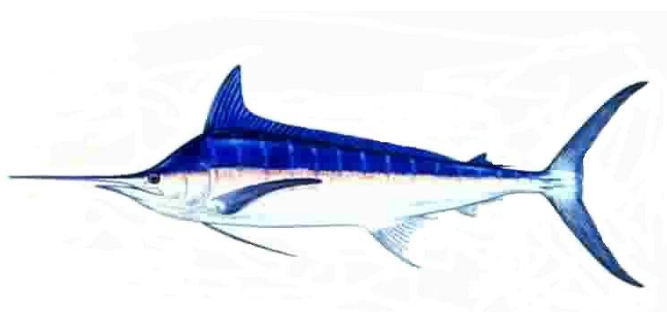
International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

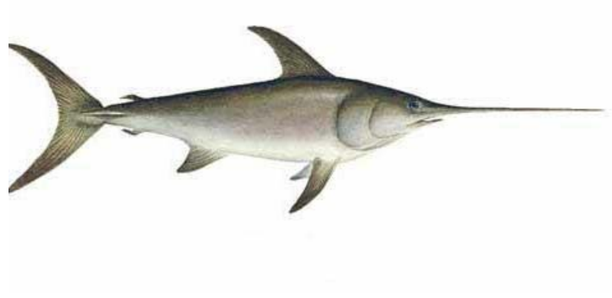
ISC/08/BILLWG-2/12

Standardization of Taiwanese distant water tuna longline catch rates for swordfish in the North Pacific, 1995-2006

Su-Zan Yeh
Institute of Oceanography
National Taiwan University
Taipei, Taiwan

Chi-Lu Sun
Institute of Oceanography
National Taiwan University
Taipei, Taiwan





[1]Working document submitted to the ISC Billfish Working Group Workshop, June 11-19, 2008, Abashiri, Hokkaido, Japan. Document not to be cited without authors' written permission.

Standardization of Taiwanese distant water tuna longline catch rates for swordfish in the North Pacific, 1995-2006*

Su-Zan Yeh and Chi-Lu Sun

Institute of Oceanography, National Taiwan University
Taipei, Taiwan

Abstract

Catch rates of swordfish for the Taiwanese longline fishery in the North Pacific Ocean was standardized using a general linear model (GLM). Three different models were used. The first model includes the variables year, area, sea surface temperature (SST), bigeye tuna catch rate (BET), yellowfin tuna catch rate (YFT), and the interaction between BET and YFT. Variables in the second model include year, area and SST, while variables in the third model include year, area, SST and number of hooks per basket (HPB). All models indicated increasing trends in standardized CPUE until 2001, thereafter CPUEs decreased gradually.

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 for swordfish caught by Taiwan’s longline vessels in the North Pacific Ocean during the period of 1995 to 2006 using general linear model (GLM) procedures, and provide preliminary descriptions of the swordfish abundance trends in the North Pacific Ocean.

* A working paper submitted to the Intercessional Workshop of the Billfish Working Groups of ISC. June 11-19, 2008, Taipei, Taiwan.

Materials and Methods

Data on catch (number of fish) and effort (number of hooks) during the period 1995-2004 were provided by Oversea Fisheries Development Council (OFDC). Information on number of hooks per basket (HPB) is only available from daily logbooks data since 1995, and was also provided by OFDC. Monthly average data of sea surface temperature (SST) on the scale of 1˚ x 1˚ square over the Pacific Ocean were obtained from the NCEP Reynolds Optimally Interpolated Sea Surface Temperature database (http://poet.jpl.nasa.gov/). All data were aggregated into monthly 5^o x 5^o cells by year, and nominal CPUE (number of swordfish per 1000 hooks) values 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, season, area (Fig. 1), SST, HPB, yellowfin tuna catch rate (YFT) and bigeye tuna catch rate (BET).

Three multiplicative models were applied to the data in this study:

Model-1:

$$\ln(CPUE_{ijklmn}+0.1) = \mu + Y_i + S_j + A_k + SST_l + YFT_n + BET_o + YFT_n{*}BET_o + \varepsilon_{ijklmno}$$

Model-2:

$$\ln(CPUE_{ijkl}+0.1) = \mu + Y_i + S_j + A_k + SST_l + \varepsilon_{ijkl}$$

Model-3:

$$\ln(CPUE_{ijklm}+0.1) = \mu + Y_i + S_j + A_k + SST_l + HPB_m + \varepsilon_{ijklm}$$

where

ln	is the natural logarithm;
$CPUE_{ijklmno}$	is the nominal catch rate (no. of fish / 1000 hooks) in year i, season j, area k, SST l, HPB m, yellowfin tuna catch rate n, and bigeye tuna catch rate p;
μ	is the overall mean;
Y_i	is year i;
S_j	is season j;
A_k	is area k;

SST_l	is sea surface temperature *l*;
HPB_m	is number of hooks per basket *m*;
YFT_n	is yellowfin tuna catch rate *n*;
BET_o	is yellowfin tuna catch rate *o*;
YFT_n*BET_o	is the interaction between YFT_n and BET_o ;
ε_{ijklmo}	is the error term, NID $(0,\sigma^2)$.

Data preparation and calculation was completed using SAS Statistical Software, Version 9.1 (PC Version).

Results and Discussion

Figs. 2 and 3 show the yearly distribution of the fishing effort and the swordfish CPUE during the period from 1995 to 2006. GLM analyses yielded three final models. The first model (same model proposed by Yeh, et al., 2007) includes the variables year, area, SST, YFT, BET, and the interaction between YFT and BET. Variables in the second model include year, area and SST, while variables in the third model include year, area, SST and HPB. The total numbers of observations for these three models were 2314, 2314 and 6583, respectively. Analysis of variance (ANOVA) tables for each of the model are shown in Tables 1-3. All of the variables except season were statistically significant ($p<0.05$). The fractions of sum of squares (i.e. R^2) explained by models 1, 2 and 3 are 0.37, 0.28, and 0.22, respectively. Frequency distributions of the standardized residuals for each of the models are normally distribution (Fig. 4).

Fig. 5 shows the least square mean (LSM) estimates of annual standardized CPUE and nominal CPUE. Between 1995 and 1999, the standardized and nominal CPUEs are similar, ranging between 0.04 and 0.17 fish per thousand hooks, with no apparent trend. After 1999 standardized and nominal CPUEs differed significantly. Nominal CPUE increased in 2000 and reached a high of approximately 0.9 fish per thousand hooks in 2001, thereafter decreasing to a level of 0.2 fish per thousand hooks. Standardized CPUEs showed a similar increase in 2000, but to much lower values (0.3 – 0.35 fish per thousand hooks). Standardized CPUEs gradually declined after 2001 in models 1 and 3, while only a slight decline was observed in model 2 after 2002.

References cited

Allen R. and R. Punsly. 1984. Catch rate as indices of abundance of yellowfin tuna, in the eastern Pacific Ocean. IATTC Bull. 18(4): 303-379.

Draper, N.R. and H. Smith. 1981. Applied regression analysis. John Wiley and Sons, Inc., New York. 708 pp.

Kimura, D.K. 1981. Standardized measures of relative abundance based on modeling log(CPUE) and their application to Pacific Ocean perch. J. Cons. Int. Explor. Mer. 39: 211-218.

Sun, C.L. and S.Z. Yeh. 1999. Standardized catch rates of yellowfin and bigeye tunas from the Taiwanese tuna fisheries in the western Pacific. Working Document SCTB12/RG-3, 15 pp.

Yeh, S.Z., C.L. Sun, S.P. Wang and Y.J. Chang, 2007. Standardization of Taiwanese distant water tuna longline catch rates for swordfish in the North Pacific Ocean. The Joint Intercessional Workshop of the Marlin (MARWG) and Swordfish (SWOWG) Working Groups of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). March 19-26, 2007, Taipei, Taiwan. ISC/07/MARWG&SWOWG-1/14.

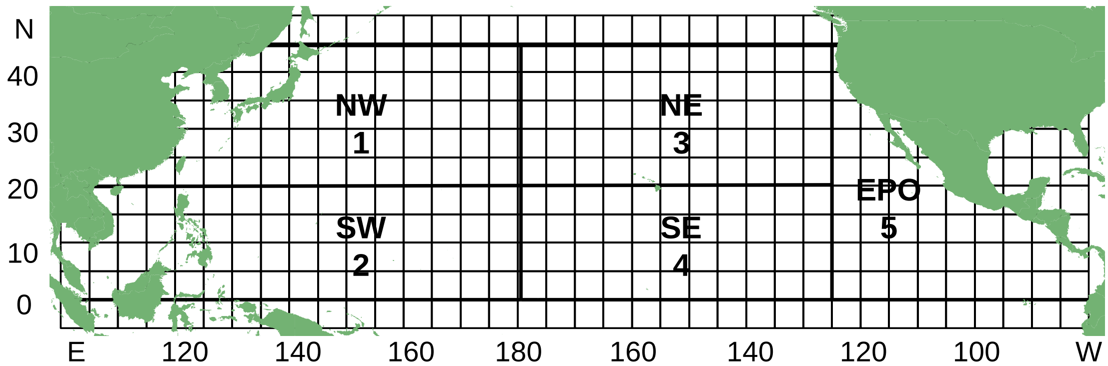


Fig. 1. Map of North Pacific Ocean showing the statistical areas for the GLM model in this study.

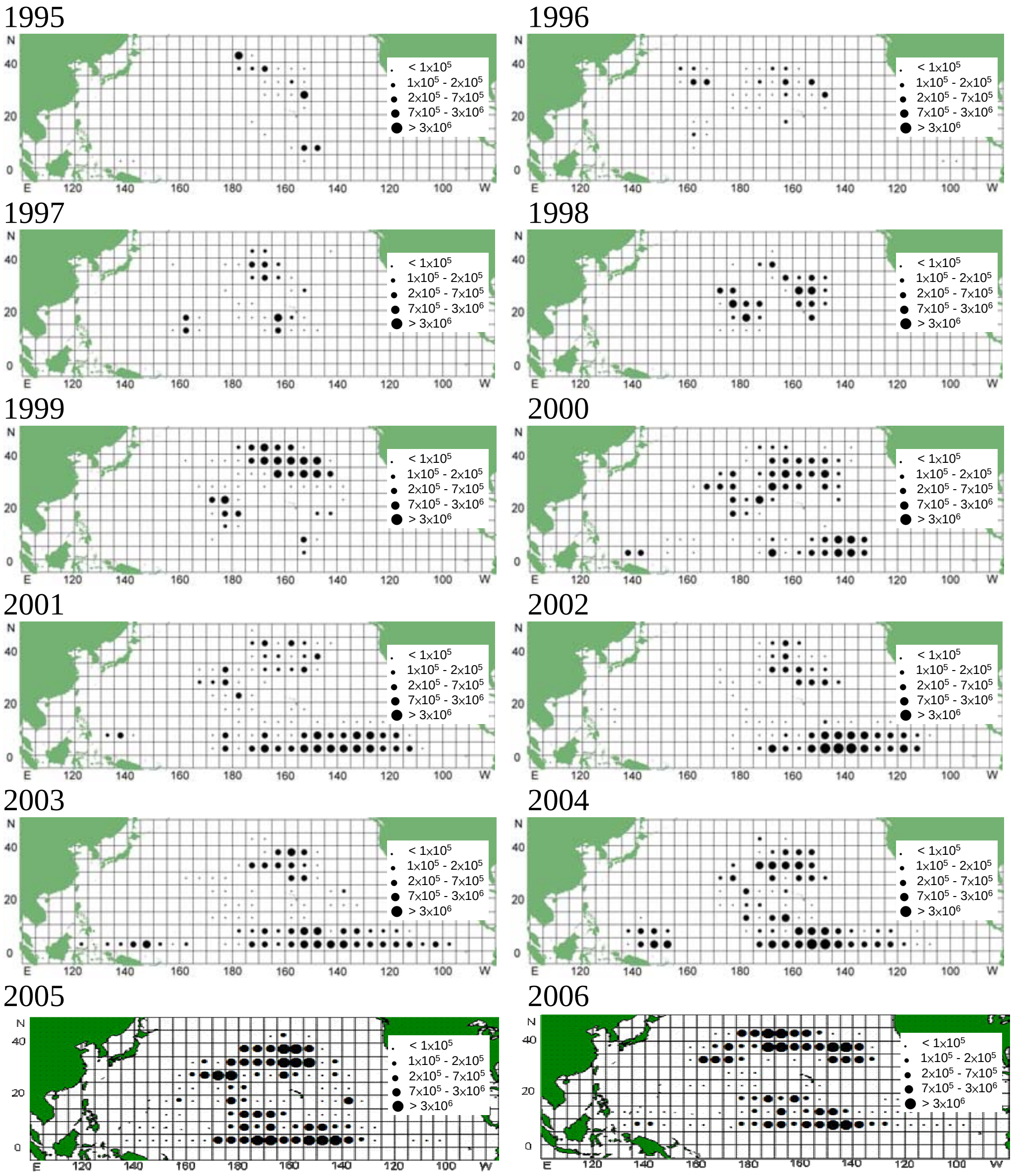


Fig. 2. The yearly distribution of fishing effort for Taiwan's longline fishery in the North Pacific Ocean during the period from 1995 to 2006 (Unit: hooks).

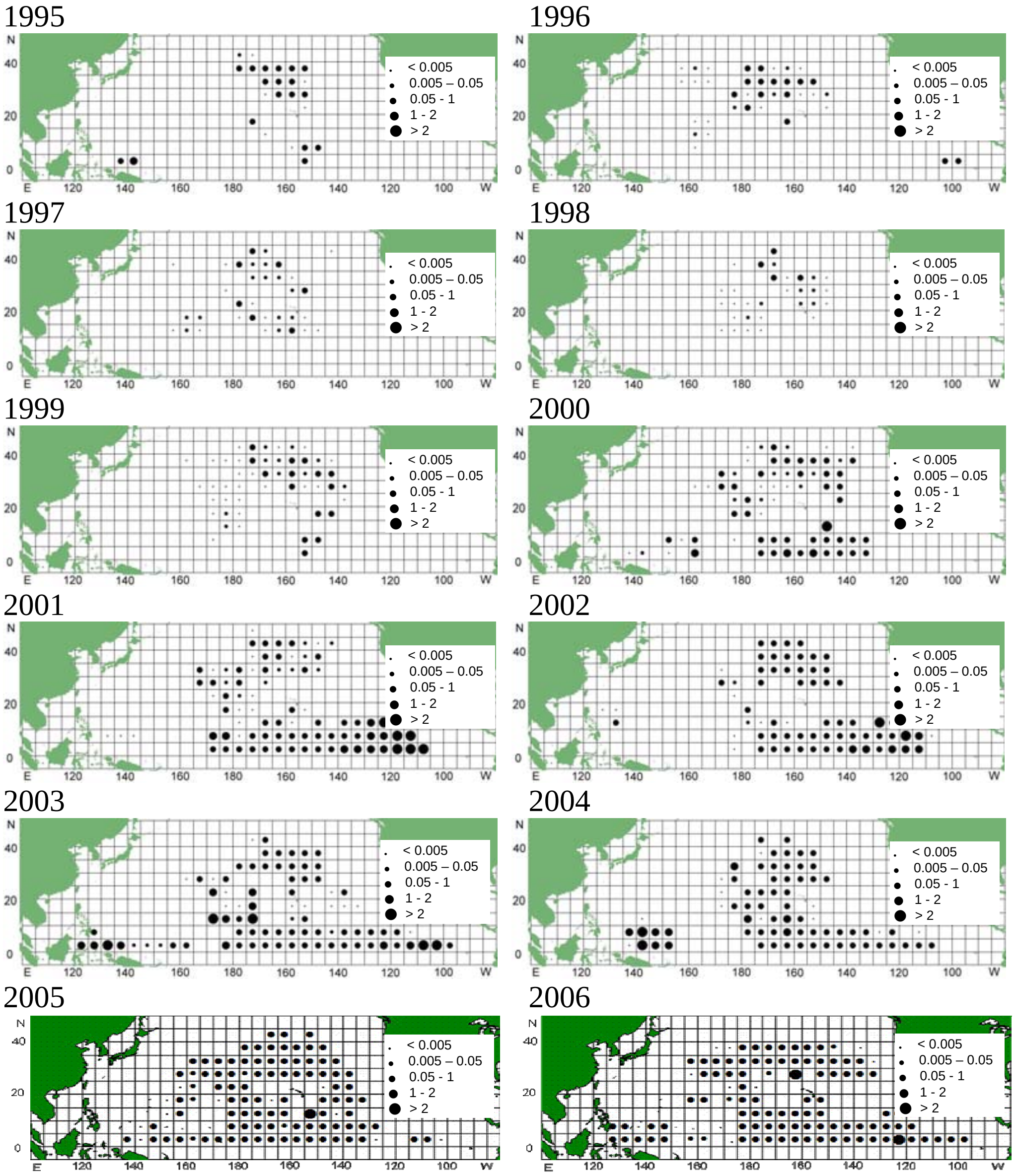


Fig. 3. The yearly distribution of swordfish CPUE for Taiwan's longline fishery in the North Pacific Ocean during the period from 1995 to 2006.

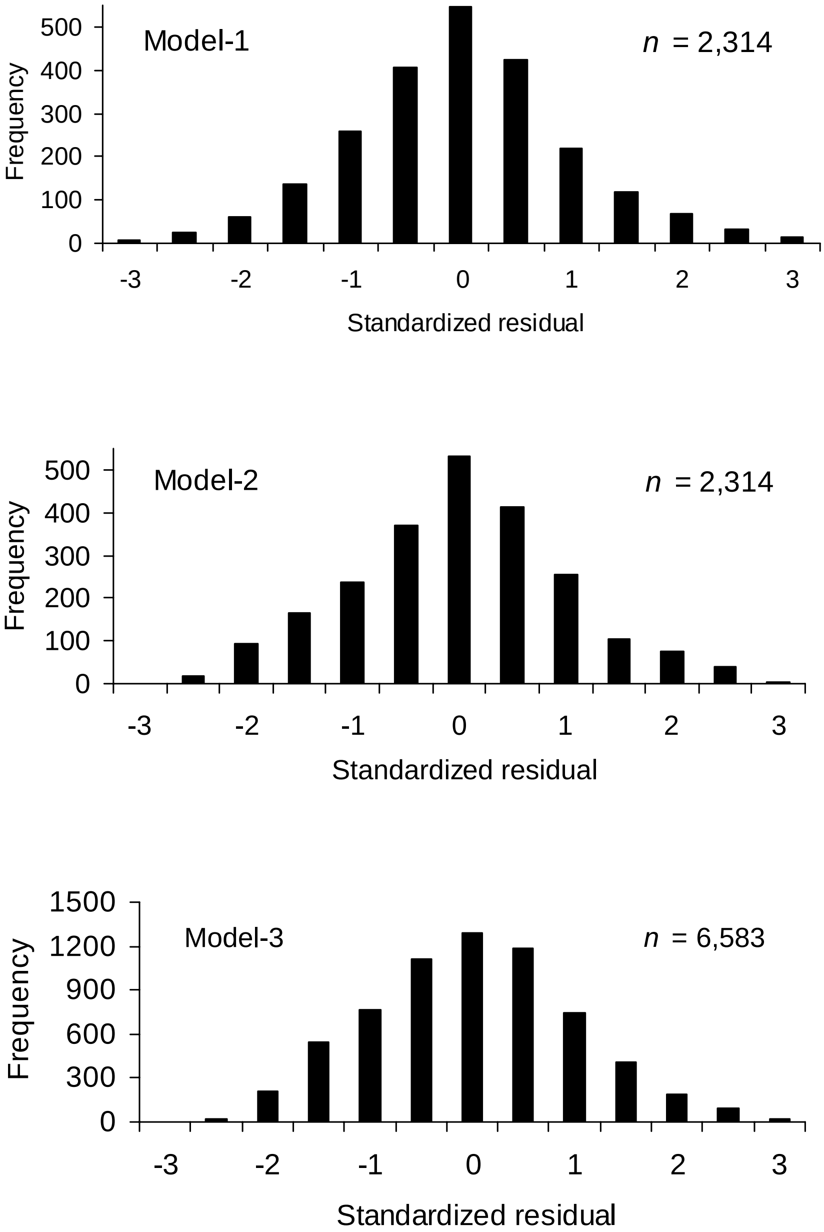


Fig. 4. Distribution of standardized residuals of the three models fitted to the swordfish CPUE data of Taiwanese longline fishery in the North Pacific, 1995-2006.

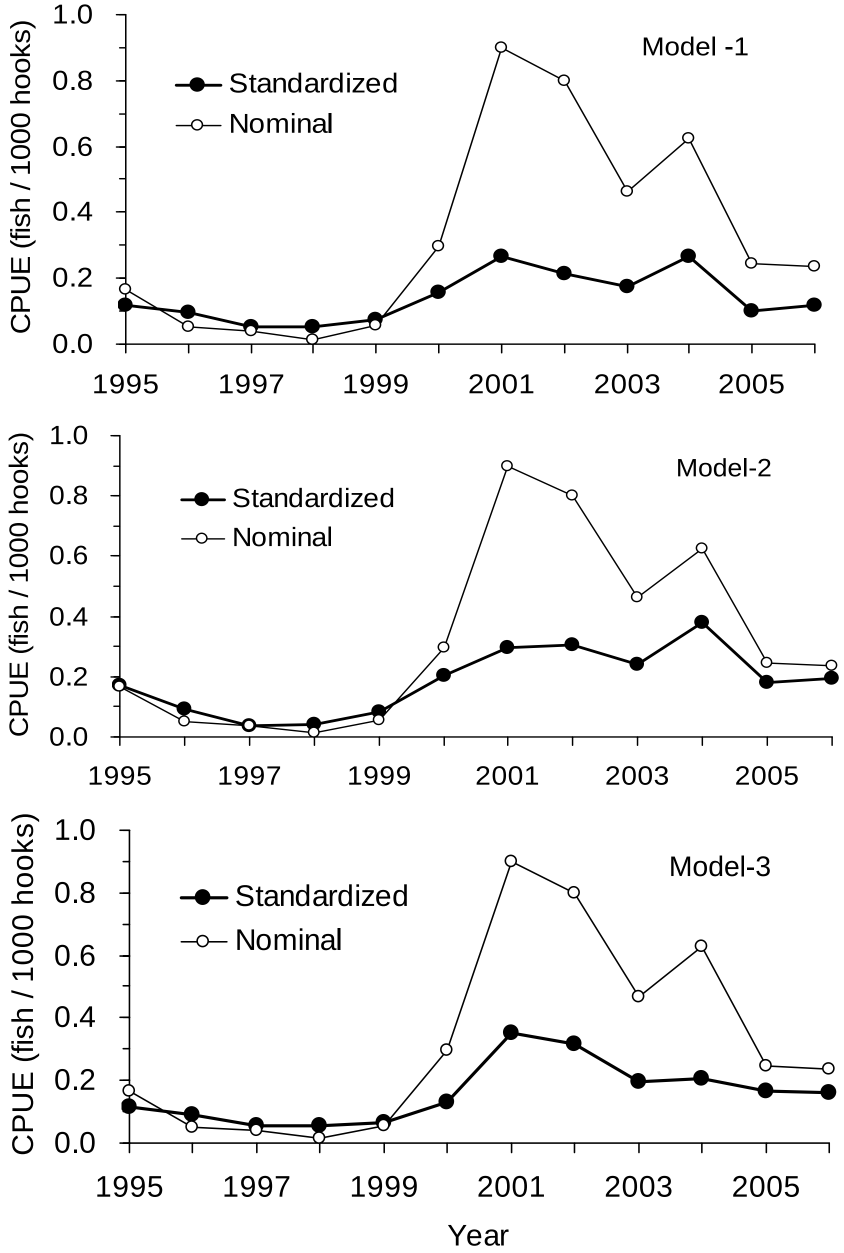


Fig. 5. Standardized and nominal swordfish CPUE of Taiwanese longline fishery in the North Pacific, 1995-2006, by three models.

Table 1. Analysis of variance results for the GLM model fitted to the swordfish CPUE data of Taiwanese longline fishery in the North Pacific, 1995-2006. (Model-1)

Class Level Information

Class	Levels	Values
Year	12	1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Season	4	1 2 3 4
area	5	1 2 3 4 5
SST	4	1 2 3 4
Alb	4	0 1 2 3
Yft	4	0 1 2 3
Bet	4	0 1 2 3

Number of Observations Used 2314

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	33	836.294921	25.342270	41.31	<.0001
Error	2280	1398.802591	0.613510		
Corrected Total	2313	2235.097512			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.374165	-65.48452	0.783269	-1.196113

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	11	147.4307286	13.4027935	21.85	<.0001
area	4	63.6187292	15.9046823	25.92	<.0001
sst	3	10.7404827	3.5801609	5.84	0.0006
yft	3	7.0673755	2.3557918	3.84	0.0093
bet	3	130.0050660	43.3350220	70.63	<.0001
yft*bet	9	30.6855332	3.4095037	5.56	<.0001

Table 2. Analysis of variance results for the GLM model fitted to the swordfish CPUE data of Taiwanese longline fishery in the North Pacific, 1995-2006. (Model-2)

Class Level Information

Class	Levels	Values
Year	12	1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Season	4	1 2 3 4
area	5	1 2 3 4 5
SST	4	1 2 3 4
Alb	4	0 1 2 3
Yft	4	0 1 2 3
Bet	4	0 1 2 3

Number of Observations Used 2314

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	18	619.312298	34.406239	48.87	<.0001
Error	2295	1615.785213	0.704046		
Corrected Total	2313	2235.097512			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.277085	-70.15010	0.839074	-1.196113

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	11	196.7851940	17.8895631	25.41	<.0001
area	4	157.9935308	39.4983827	56.10	<.0001
SST	3	5.7615571	1.9205190	2.73	0.0426

Table 3. Analysis of variance results for the GLM model fitted to the swordfish CPUE data of Taiwanese longline fishery in the North Pacific, 1995-2006. (Model-3)

Class Level Information

Class	Levels	Values
Year	12	1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Season	4	1 2 3 4
Area	5	1 2 3 4 5
HPB	4	1 2 3 4
SST	4	1 2 3 4

Number of Observations Used 6583

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	1423.480731	67.784797	86.52	<.0001
Error	6561	5140.420584	0.783481		
Corrected Total	6582	6563.901314			

R-Square	Coeff Var	Root MSE	LNCPUE Mean
0.216865	-72.76854	0.885145	-1.216384

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Year	11	379.6256348	34.5114213	44.05	<.0001
Area	4	136.5509183	34.1377296	43.57	<.0001
HPB	3	33.2046878	11.0682293	14.13	<.0001
SST	3	10.9733177	3.6577726	4.67	0.0029