# Standardized CPUE of Central and Western Pacific Bigeye Tuna from Taiwanese Tuna Longline Fisheries

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## Introduction

Taiwan's distant-water tuna longline vessels have been fishing in the Pacific Ocean since 1963, with the target species being albacore (Sun and Yeh 1992, 1993, 1994, 1997). Taiwan's offshore tuna longline fleets based in ports belonging to western Pacific Island countries have been fishing in the western Pacific since 1988 where they target yellowfin and bigeye tuna. The purpose of this paper is to standardize the catch per unit effort (CPUE) of bigeye tuna caught in the central and western Pacific by these two fleets. The standardized CPUE may then find possible use in the stock assessments of the Western Pacific Bigeye Tuna Research Group.

The general linear modeling technique was applied to estimate annual CPUE's of the distant-water and offshore longline data for the periods 1967-1996 and 1988-1997, respectively.

## Materials and Methods

*Distant-water longline fishery*

Catch was represented by the number of fish taken and effort was expressed in number of hooks used. These variables were presented by month in a $5^{o}$x $5^{o}$ square area during the period 1967-1996. The nominal CPUE value represented catch in number of bigeye per 1000 hooks.

The main variables chosen to implement the general linear model (GLM ) analyses (Kimura 1981, Allen and Punsly 1984, Draper and Smith 1981) were year, month, WPYF area, and the catch rates of albacore and yellowfin tuna treated as class variables.

The multiplicative model used in this analysis is

$$\ln\,(CPUE_{ijklm}+1) = \mu + Y_i + M_j + A_k + ALB_l + YFT_m + interactions + \varepsilon_{ijklm}$$

where

| | |
|---|---|
| ln | is the natural logarithm; |
| $CPUE_{ijklm}$ | is the nominal catch rate (no. of fish / 1000 hooks) in year $i$, month $j$, WPYF area $k$, albacore catch rate $l$, and yellowfin catch rate $m$; |
| $\mu$ | is the overall mean; |
| $Y_i$ | is year $i$; |
| $M_j$ | is month $j$; |
| $A_k$ | is WPYF area $k$; |
| $ALB_l$ | is albacore catch rate $l$; |
| $YFT_m$ | is yellowfin catch rate $m$; |
| interactions | is the two-way interactions among main effects except year; |
| $\varepsilon_{ijklm}$ | is the error term, NID $(0,\sigma^2)$. |

*Offshore longline fishery*

Catch was represented by the number of fish taken, and effort was expressed in number of hooks used. These variables were presented by month in a $5^{o}$x $5^{o}$ square area during the period 1988-1997. The nominal CPUE value represented catch in number of bigeye per 1000 hooks.

The main effects chosen to implement the GLM analyses were year, month, WPYF area, and the catch rates of yellowfin tuna treated as a class variable.

The multiplicative model used in this analysis is

$$\ln\,(CPUE_{ijkl}+1) = \mu + Y_i + M_j + A_k + YFT_l + interactions + \varepsilon_{ijkl}$$

where

| | |
|---|---|
| ln | is the natural logarithm; |
| $CPUE_{ijkl}$ | is the nominal catch rate (no. of fish / 1000 hooks) in year $i$, month $j$, WPYF area $k$, and yellowfin catch rate $l$; |
| $\mu$ | is the overall mean; |
| $Y_i$ | is year $i$; |
| $M_j$ | is month $j$; |
| $A_k$ | is WPYF area $k$; |
| $YFT_l$ | is yellowfin catch rate $l$; |
| interactions | is the two-way interactions among main effects except year; |

$\varepsilon_{ijkl}$ is the error term, NID $(0,\sigma^2)$.

Data preparation and calculation employing SAS Statistical Software, Version 6.12, were performed on personal computer.

## Results and Discussion

*Distant-water longline fishery*

The total number of observations for this analysis was 8,259. The frequency distribution of the standardized residuals for all variables combined effects is very close to that of the normal distribution (Fig. 1A).

The results of using the GLM analysis of variance (ANOVA) to examine the logged catch rate for differences among variables (year, month, area, the catch rates of albacore and yellowfin tuna, and their interactions) are shown in Table 1. All of the main variables as well as the whole model are statistically significant ($p<0.01$). The fraction of sum of squares explained by the model (i.e. $R^2$) is 0.40.

Figure 2 shows the trend of standardized CPUE and nominal CPUE. There is a downward trend of CPUE during 1967 to 1980. The CPUE dropped to below 1 fish per thousand hooks and fluctuated between 0.83 and 0.38 fish per thousand hooks during 1981 to 1992. The CPUE decreased to a low, stable condition, between 0.54 to 0.32 fish per thousand hooks during 1993-1996.

*Offshore longline fishery*

The total number of observations for this analysis was 1,653. Preliminary analyses indicated that area is statistically insignificant. It was therefore removed from the model. The results of ANOVA for the final model are shown in Table 2. The rate of variability explained by the model (i.e. $R^2$) was fairly low (0.22). The overall distribution of standardized residual (Figure 1B) is close to the normal curve.

Figure 3 shows the trend of standardized and nominal CPUE. The nominal CPUE is always higher than standardized CPUE except in 1991. The CPUE increased gradually from 1.9 fish per thousand in 1989 to the maximum of 4.0 fish per thousand hooks in 1993. Since then, the CPUE decreased again and remained between 2.5 to 2.9 fish per thousand hooks during 1995 to 1996. The CPUE was 2.7 fish per thousand hooks in 1997.

The CPUE for the offshore longline fishery was 3.0 (in 1990) to 8.5 (in 1993) times higher than the CPUE for distant-water longline fishery. The reasons are that bigeye tuna is the target species by offshore longline fleets while the albacore is the target species by distant-water longline fleet.

**References cited**


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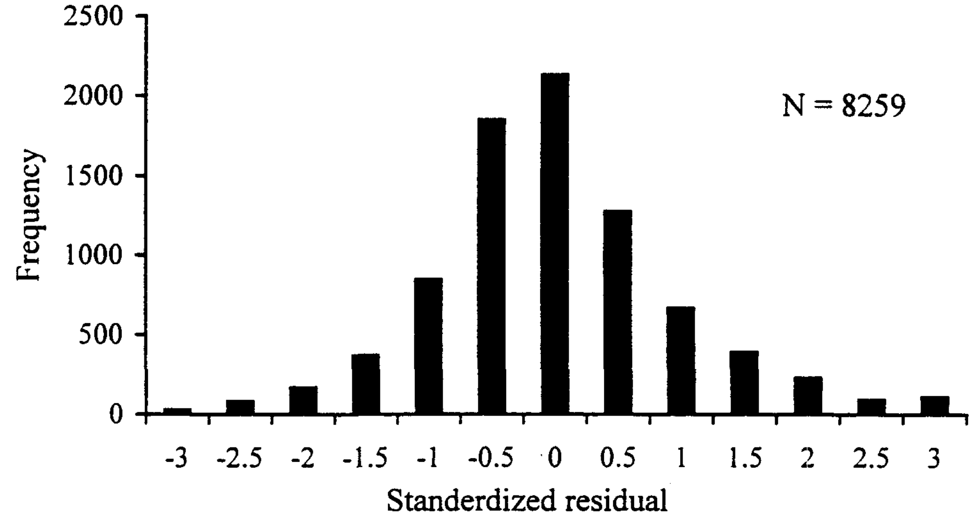
(A)




(B)

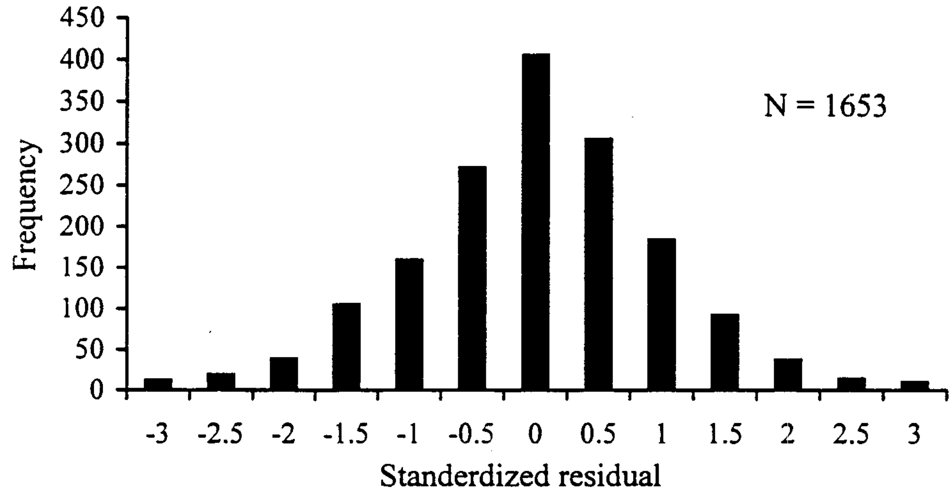



Figure 1. Distribution of standerdized residuals of the models fitted to the bigeye CPUE data from Taiwanese distant-water longline (A) and offshore longline (B) fisheries in the western Pacific Ocean.

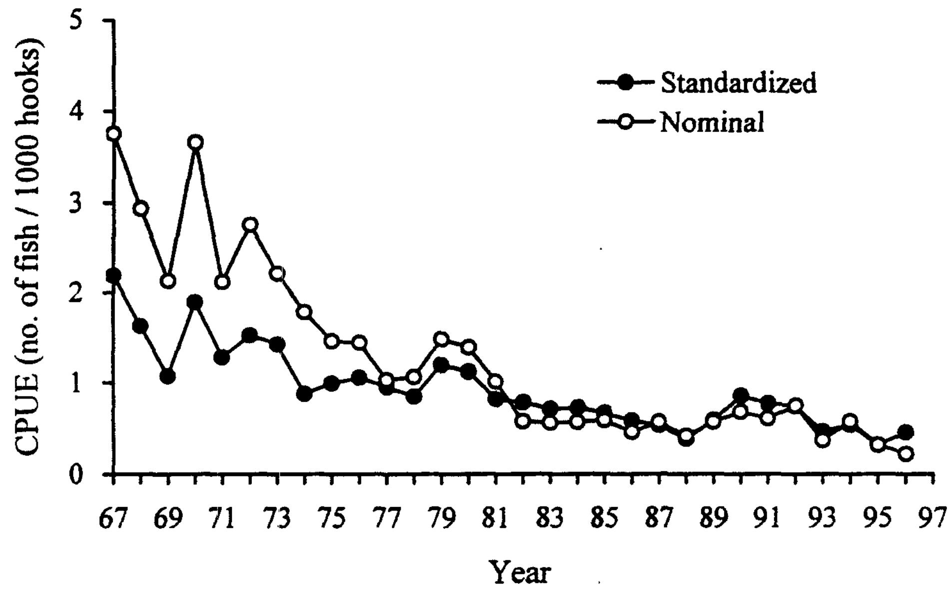



Figure 2. Standardized and nominal bigeye CPUE for Taiwanese distant-water longline fishery in the western Pacific, 1967-1996.

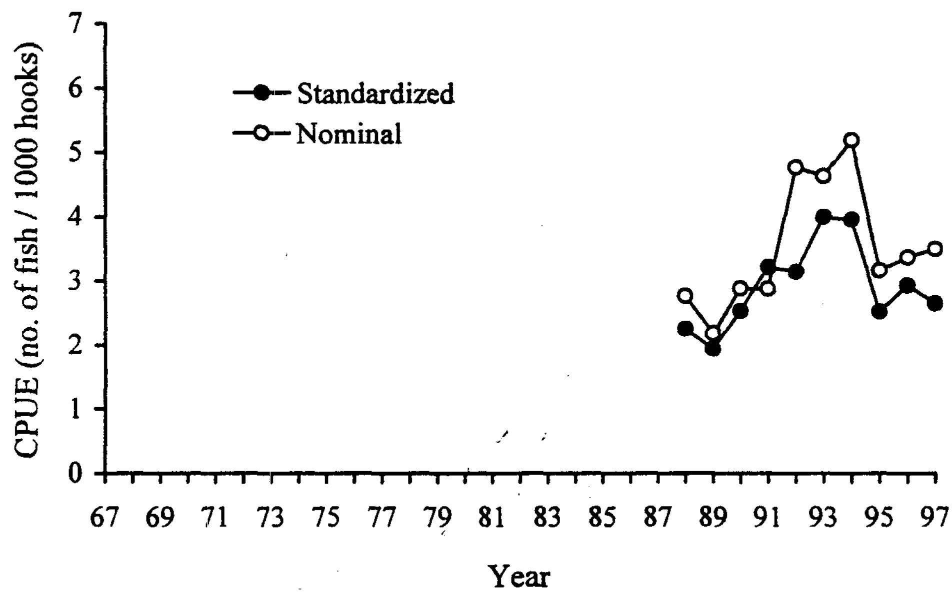



Figure 3. Standardized and nominal bigeye CPUE for Taiwanese offshore longline fishery in the western Pacific, 1988-1997.

Table 1. Analysis of variance results for the GLM model fitted to the bigeye CPUE data from Taiwanese distant-water longline fishery.

Class Level Information

| Class | Levels | Values |
|---|---|---|
| YEAR | 30 | 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 |
| MONTH | 12 | 1 2 3 4 5 6 7 8 9 10 11 12 |
| AREA | 5 | 3 4 5 6 7 |
| ALB | 5 | 0 1 2 3 4 |
| YFT | 6 | 0 1 2 3 4 5 |

Number of observations in data set = 8259

Dependent Variable: LNCPUE

| Source | DF | Sum of Squares | F Value | Pr > F |
|---|---|---|---|---|
| Model | 192 | 1260.48732533 | 28.50 | 0.0001 |
| Error | 8066 | 1858.05019278 | | |
| Corrected Total | 8258 | 3118.53751811 | | |

| R-Square | C.V. | LNCPUE Mean |
|---|---|---|
| 0.404192 | 69.53812 | 0.69020269 |

| Source | DF | Type III SS | F Value | Pr > F |
|---|---|---|---|---|
| YEAR | 29 | 215.33029717 | 32.23 | 0.0001 |
| MONTH | 11 | 11.16166789 | 4.40 | 0.0001 |
| AREA | 4 | 32.38531732 | 35.15 | 0.0001 |
| ALB | 4 | 27.40039039 | 29.74 | 0.0001 |
| YFT | 5 | 57.01996427 | 49.51 | 0.0001 |
| MONTH*ALB | 44 | 27.84766392 | 2.75 | 0.0001 |
| MONTH*YFT | 55 | 18.51272643 | 1.46 | 0.0148 |
| AREA*YFT | 20 | 31.23160157 | 6.78 | 0.0001 |
| ALB*YFT | 20 | 22.20452868 | 4.82 | 0.0001 |