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# Updated CPUE of Central and Western Pacific Yellowfin Tuna from Taiwanese Distant-Water Fisheries

by

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## Introduction

Taiwan's distant-water tuna longline (or simply Taiwanese longline) vessels have been fishing in the Pacific Ocean since 1963, with the target species being albacore (Sun and Yeh 1992, 1993a, 1994). Taiwan's distant-water tuna purse seine (Taiwanese purse seine) vessels have been operating in the western Pacific since 1982, with the target species being skipjack and yellowfin tuna (Sun and Yeh 1992, 1993b, 1994).

The purpose of this paper is to update the standardized catches per unit effort (CPUE's), which have been studied by Sun and Yeh (1994), for yellowfin tuna caught in the central and western Pacific by the two fleets mentioned above. The standardized CPUE's may then find possible use in the stock assessments of the Western Pacific Yellowfin Tuna Research Group (WPYRG).

The general linear modeling technique was applied to estimate annual CPUE's of the longline and purse seine data for the periods 1967-1995 and 1988-1996, respectively.

## Materials and Methods

### Taiwanese 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°x 5° square area during the period 1967-1995. The nominal CPUE value represented catch in number of yellowfin per 1000 hooks.

The detailed procedure for standardization of the Taiwanese longline CPUE using the general linear model (GLM) method (Kimura 1981, Allen and Punsly 1984, Draper and Smith 1986) was described by Sun and Yeh (1993a). The main effects chosen to implement the GLM analyses were year, month, WPYF area, spawning season-area, and the catch rates of albacore and bigeye tuna treated as class variables (new effects added, compared to Sun and Yeh, 1994. Also added is the interaction term between month and WPYF area).

The multiplicative model used in this analysis is

$$\ln(CPUE_{ikjlmn}+1)=\mu+Y_i+M_j+A_k+S_l+ALB_m+BET_n+M_jA_k+\varepsilon_{ijklmn}$$

where

| | |
|---|---|
| ln | is the natural logarithm; |
| $CPUE_{ijklmn}$ | is the nominal catch rate (no. of fish / 1000 hooks) in year *i*, month *j*, WPYF area *k*, spawning season-area *l*, albacore catch rate *m*, and bigeye catch rate *n*; |
| $\mu$ | is the overall mean; |
| $Y_i$ | is year *i*; |
| $M_j$ | is month *j*; |
| $A_k$ | is WPYF area *k*; |
| $S_l$ | is spawning season-area *l* (peak or nonpeak); |
| $ALB_m$ | is albacore catch rate *m*; |
| $BET_n$ | is bigeye catch rate *n*; |
| $M_jA_k$ | is the interaction between month and WPYF area; |
| $\varepsilon_{ijklmn}$ | is the error term, NID $(0,\sigma^2)$. |

**Taiwanese purse seine fishery**

For the Taiwanese purse seine fishery, catch was expressed as the tonnage of fish caught, and effort was represented by the number of days fished. These variables were presented by month in a 5°x 5° square area during the period 1988-1996. The nominal CPUE value represented catch in tonnage of yellowfin per day.

The detailed procedure for standardization of the Taiwanese purse seine CPUE using the GLM method was also described by Sun and Yeh (1993b). The main effects chosen to implement the GLM analyses were year, month, WPYF area, set type, spawning season-area, and the catch rate of skipjack treated as a class variable (new effect added, compared to Sun and Yeh, 1994).

*The multiplicative model used in this analysis is*

$$\ln(CPUE_{ijklmn} + 1) = \mu + Y_i + M_j + A_k + T_l + S_m + SKJ_n + \varepsilon_{ijklmn}$$

where

| | |
|---|---|
| ln | is the natural logarithm; |
| $CPUE_{ijklmn}$ | is the nominal catch rate (mt / day fished) in year $i$, month $j$, WPYF area $k$, set type $l$, spawning season-area $m$, and skipjack catch rate $n$; |
| $\mu$ | is the overall mean; |
| $Y_i$ | is year $i$; |
| $M_j$ | is month $j$; |
| $A_k$ | is WPYF area $k$; |
| $T_l$ | is the set type $l$, |
| $S_m$ | is spawning season-area $m$ (peak or nonpeak); |
| $SKJ_n$ | is skipjack catch rate $n$; and |
| $\varepsilon_{ijklmn}$ | is the error term, NID$(0,\sigma^2)$. |

Data preparation and calculation employing SAS Statistical Software, Version 6.04, were performed on personal computer.

## Results and Discussion

### Taiwanese longline fishery (Ow - albacore).

The total number of observations for this analysis is 8,018. The frequency distribution of the standardized residual for all variables' combined effects is shown in Figure 1A. The combined distribution of the standardized residual is very close to that of the normal distribution.

The results of using the GLM analysis of variance (ANOVA) to examine the logged catch rate for differences among variables (year, month, area, spawning season-area, and the catch rates of albacore and bigeye tuna) are shown in Table 1a. All of the main variables as well as the whole model are statistically significant ($p<0.01$). The rate of variability explained by the model (i.e. $R^2$) is 0.57.

Figure 2a shows the least square mean (LSM) estimates of annual CPUE and their associated relative 95% confidence limits. There is a downward trend of CPUE after 1971 until 1977. An increase is apparent during the 1978-1980 period, followed by a decrease during 1981-1984 and a slight increase during 1985-1988. The CPUE decreased again in 1989, and from 1989 to 1995, the level maintains a low, stable condition.

Figure 3a compares the standardized CPUE with the nominal CPUE. The trend is similar although after1980 the standardized CPUE is generally slightly higher than the nominal CPUE.

Table 2a shows the analysis of variance results when the same Taiwanese longline CPUE data was fitted to the model used in Sun and Yeh, 1994. The results indicate that adding catch rates of albacore and bigeye did improve the fit of the model, but not much. This result was not what we would expect when we compare it to the work of Miyabe (1994), in which the inclusion of bigeye catch rate increases r-square from 40% to 90% for Japanese longline data.

**Taiwanese purse seine fishery**

The total number of observations for this analysis is 2,016. After the first run of ANOVA, the results indicate that two main variables, area and spawning season-area, are statistically insignificant ($p>0.5$). They were therefore removed from the model.

The results of ANOVA for the altered model are shown in Table 1b. The remaining four variables (year, month, set type, and skipjack catch rate) as well as the whole model are statistically significant ($p<0.01$). The rate of variability explained by the model (i.e. $R^2$) is fairly low (0.21). The overall distribution of standardized residual (Figure 1B) is close to the normal curve.

Figure 2b shows the LSM estimates of annual CPUE and the lower and upper 95% confidence limits. The CPUE has increased since 1991 to a maximum of 4.5 mt per day in 1993. Afterward, the CPUE decreased sharply to the lowest level of 0.8 mt per day in 1996.

In the Taiwanese purse seine fishery (Figure 3b) the standardized CPUE and the nominal CPUE have similar trends, although the nominal CPUE between 1992 and 1995 is significantly higher.

Including skipjack catch rate only slightly improves the model fitting (Tables 1b and 2b) as was similarly shown in the Taiwanese longline fishery when adding albacore and bigeye.

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Table 1a. Analysis of variance results for the GLM model fitted to the yellowfin CPUE data from Taiwanese longline fishery.

Number of observations in data set = 8018

General Linear Models Procedure

Dependent Variable: LNCPUE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 97 | 4486.34261299 | 46.25095477 | 106.64 | 0.0 |
| Error | 7920 | 3435.14735910 | 0.43373073 | | |
| Corrected Total | 8017 | 7921.48997210 | | | |

| R-Square | C.V. | Root MSE | LNCPUE Mean |
|---|---|---|---|
| 0.566351 | 51.43247 | 0.65858236 | 1.28047986 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YEAR | 28 | 752.41693332 | 26.87203333 | 61.96 | 0.0 |
| MONTH | 11 | 14.57037538 | 1.32457958 | 3.05 | 0.0004 |
| AREA | 4 | 423.01506247 | 105.75376562 | 243.82 | 0.0001 |
| SPAWN | 1 | 53.83805259 | 53.83805259 | 124.13 | 0.0001 |
| ALB | 5 | 104.75502973 | 20.95100595 | 48.30 | 0.0001 |
| BET | 4 | 208.64509500 | 52.16127375 | 120.26 | 0.0001 |
| MONTH*AREA | 44 | 132.82376967 | 3.01872204 | 6.96 | 0.0001 |

Table 1b. Analysis of variance results for the GLM model fitted to the yellowfin CPUE data from Taiwanese purse seine fishery.

Number of observations in data set = 2016

General Linear Models Procedure

Dependent Variable: LNCPUE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 26 | 558.39333936 | 21.47666690 | 20.00 | 0.0001 |
| Error | 1989 | 2135.64433064 | 1.07372767 | | |
| Corrected Total | 2015 | 2694.03767000 | | | |

| R-Square | C.V. | Root MSE | LNCPUE Mean |
|---|---|---|---|
| 0.207270 | 86.03179 | 1.03620831 | 1.20444811 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YEAR | 8 | 238.93827500 | 29.86728438 | 27.82 | 0.0001 |
| MONTH | 11 | 51.59261179 | 4.69023744 | 4.37 | 0.0001 |
| SETTYPE | 3 | 114.71214630 | 38.23738210 | 35.61 | 0.0001 |
| SKJ | 4 | 30.67848824 | 7.66962206 | 7.14 | 0.0001 |

Table 2a. Analysis of variance results for the GLM model (of 1994) fitted to the yellowfin CPUE data from Taiwanese longline fishery.

Number of observations in data set = 8018

General Linear Models Procedure

Dependent Variable: LNCPUE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 44 | 3992.70023806 | 90.74318723 | 184.15 | 0.0 |
| Error | 7973 | 3928.78973403 | 0.49276179 | | |
| Corrected Total | 8017 | 7921.48997210 | | | |

| R-Square | C.V. | Root MSE | LNCPUE Mean |
|---|---|---|---|
| 0.504034 | 54.82085 | 0.70196993 | 1.28047986 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YEAR | 28 | 1148.75197635 | 41.02685630 | 83.26 | 0.0 |
| MONTH | 11 | 50.40357303 | 4.58214300 | 9.30 | 0.0001 |
| SPCAREA | 4 | 1465.37838234 | 366.34459559 | 743.45 | 0.0 |
| SPAWN | 1 | 231.50688365 | 231.50688365 | 469.82 | 0.0001 |

Table 2b. Analysis of variance results for the GLM model (of 1994) fitted to the yellowfin CPUE data from Taiwanese purse seine fishery.

Number of observations in data set = 2016

General Linear Models Procedure

Dependent Variable: LNCPUE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 22 | 527.71485112 | 23.98703869 | 22.07 | 0.0001 |
| Error | 1993 | 2166.32281888 | 1.08696579 | | |
| Corrected Total | 2015 | 2694.03767000 | | | |

| R-Square | C.V. | Root MSE | LNCPUE Mean |
|---|---|---|---|
| 0.195883 | 86.56052 | 1.04257652 | 1.20444811 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| YEAR | 8 | 278.52060270 | 34.81507534 | 32.03 | 0.0001 |
| MONTH | 11 | 51.51724518 | 4.68338593 | 4.31 | 0.0001 |
| SETTYPE | 3 | 141.32624192 | 47.10874731 | 43.34 | 0.0001 |

# (A)

```
FREQUENCY

2000 +                                 ***
     |                                 ***                 N = 8,018
1600 +                            ***  ***
     |                            ***  ***  ***
1200 +                            ***  ***  ***
     |                       ***  ***  ***  ***
 800 +                       ***  ***  ***  ***  ***
     |                       ***  ***  ***  ***  ***
 400 +                  ***  ***  ***  ***  ***  ***  ***
     |             ***  ***  ***  ***  ***  ***  ***  ***  ***  ***
      -------------------------------------------------------------------
        -3.0 -2.5 -2.0 -1.5 -1.0 -0.5  0.0  0.5  1.0  1.5  2.0  2.5  3.0

                            STD_RES MIDPOINT
```

# (B)

```
FREQUENCY

 350 +                            ***       ***
     |                       ***  ***  ***  ***
 300 +                       ***  ***  ***  ***                N = 2,016
     |                       ***  ***  ***  ***
 250 +                       ***  ***  ***  ***  ***
     |                       ***  ***  ***  ***  ***
 200 +                       ***  ***  ***  ***  ***
     |                       ***  ***  ***  ***  ***
 150 +                  ***  ***  ***  ***  ***  ***
     |                  ***  ***  ***  ***  ***  ***  ***
 100 +                  ***  ***  ***  ***  ***  ***  ***
     |                  ***  ***  ***  ***  ***  ***  ***
  50 +             ***  ***  ***  ***  ***  ***  ***  ***  ***
     |             ***  ***  ***  ***  ***  ***  ***  ***  ***  ***
      -------------------------------------------------------------------
        -3.0 -2.5 -2.0 -1.5 -1.0 -0.5  0.0  0.5  1.0  1.5  2.0  2.5  3.0

                            STD_RES MIDPOINT
```

Figure 1. Distribution of standardized residuals of the models fitted to the yellowfin CPUE data from (A) Taiwanese longline, and (B) Taiwanese purse seine fishery in the werstern Pacific Ocean.

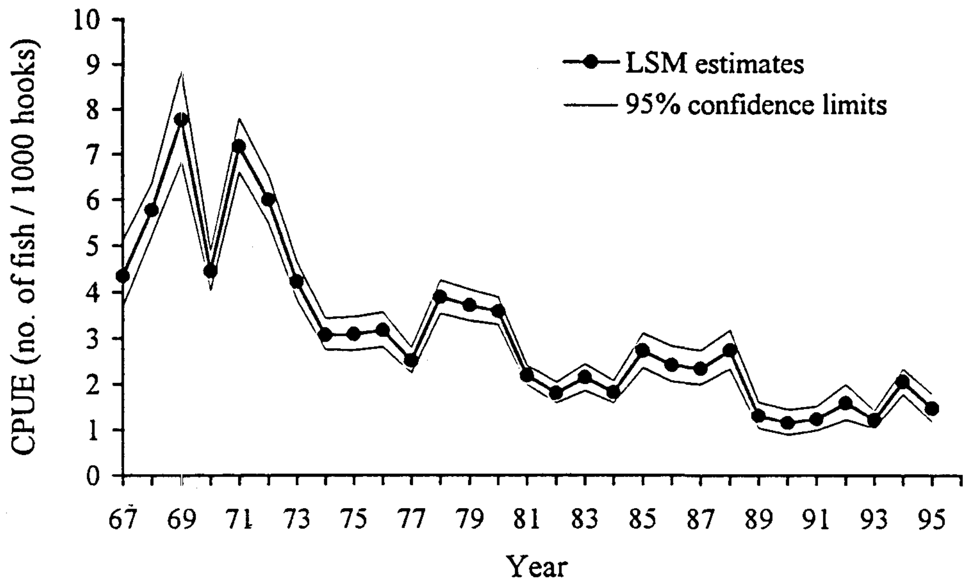


Figure 2a. Least square mean estimates and 95% confidence limits of standardized yellowfin CPUE for Taiwanese longline fishery in the western Pacific, 1967-1995.

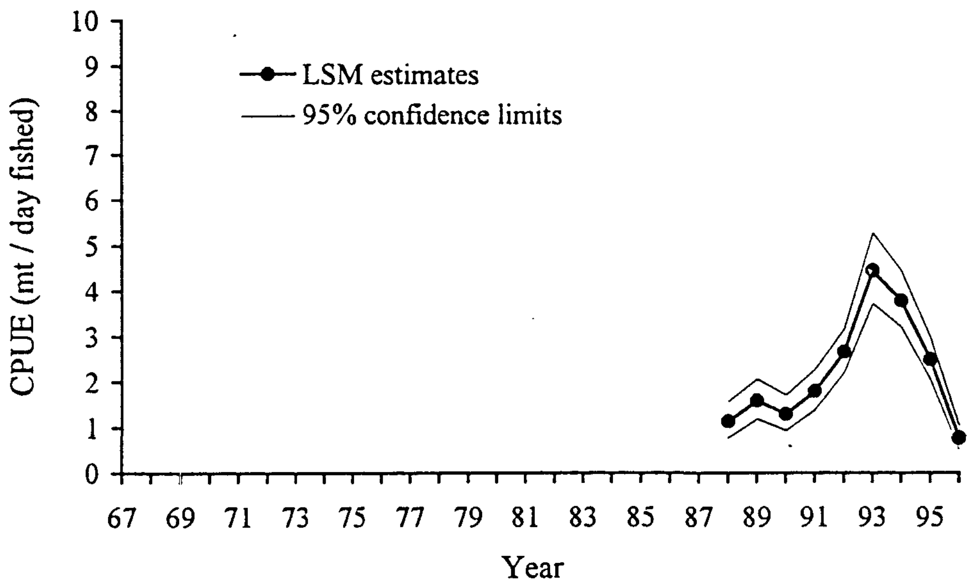


Figure 2b. Least square mean estimates and 95% confidence limits of standardized yellowfin CPUE for Taiwanese purse seine fishery in the western Pacific, 1988-1996.

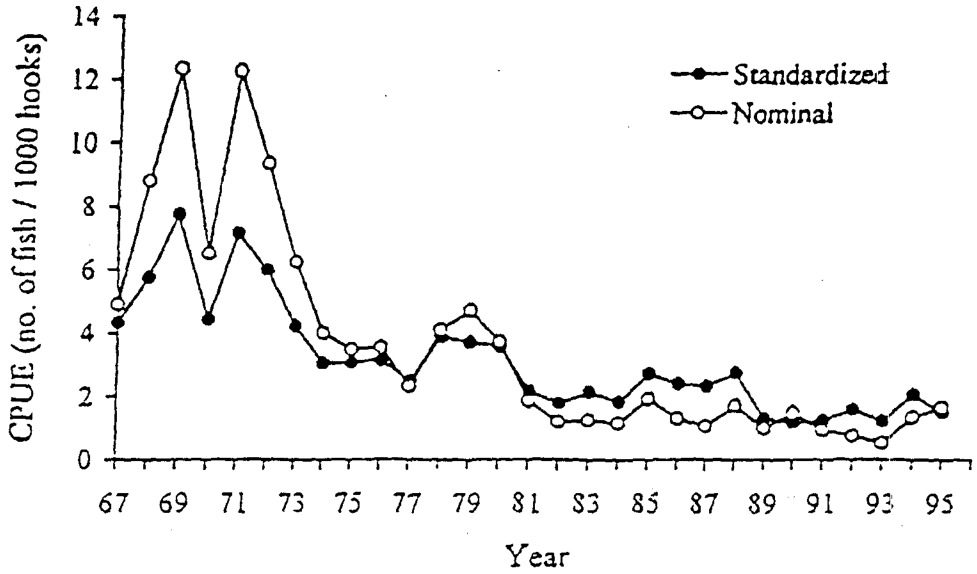


Figure 3a. Standardized and nominal yellowfin CPUE for Taiwanese longline fishery in the western Pacific, 1967-1995.

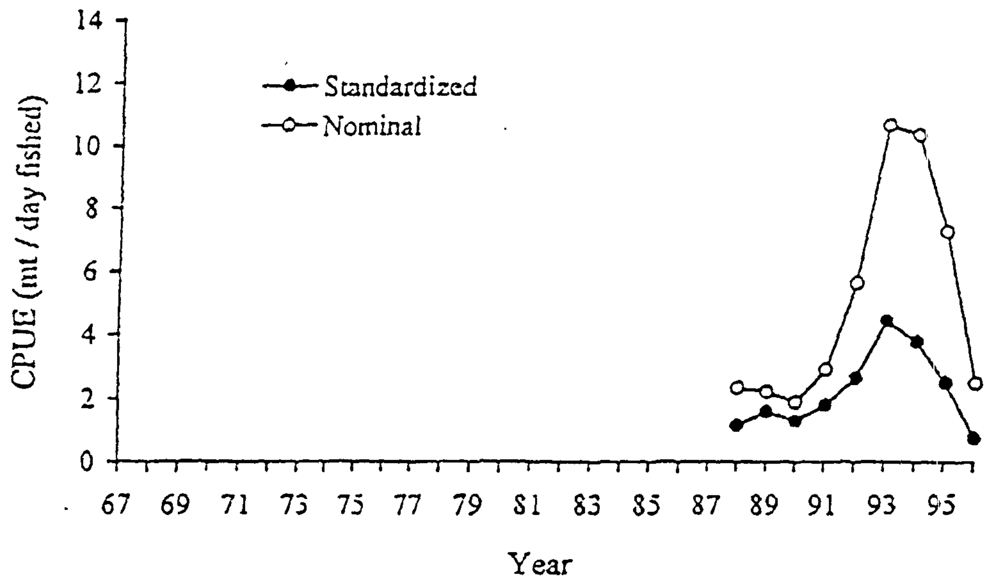


Figure 3b. Standardized and nominal yellowfin CPUE for Taiwanese purse seine fishery in the western Pacific, 1988-1996.