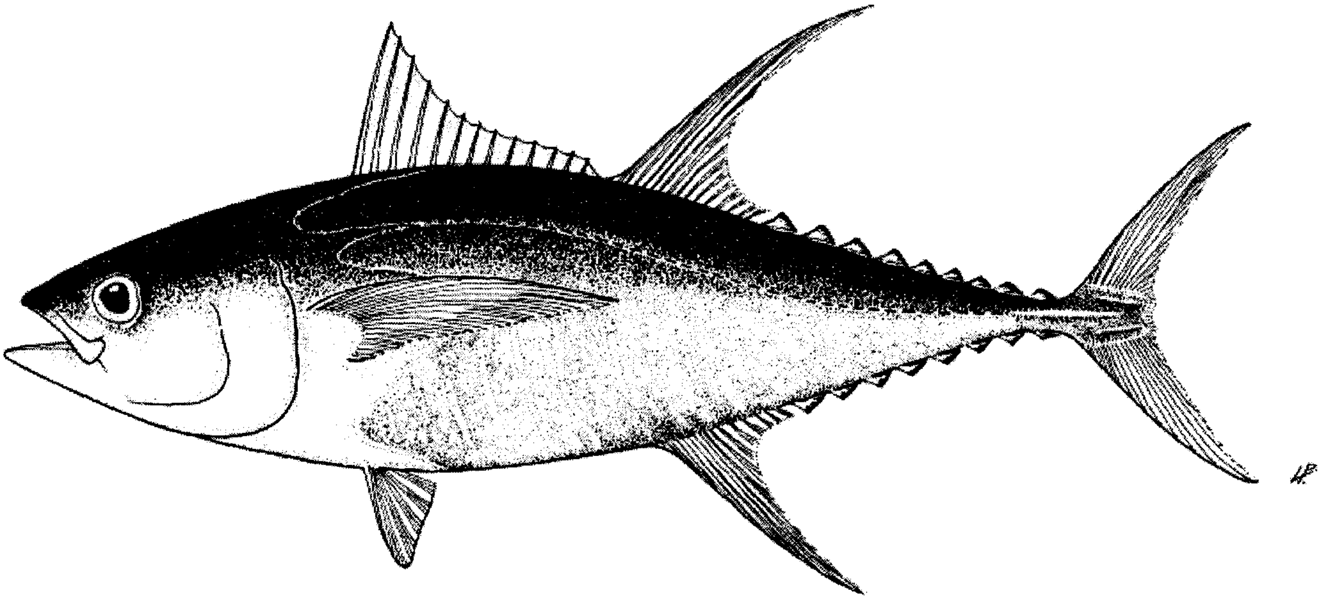
13th Meeting of the Standing Committee on Tuna and Billfish

SCTB 13
Noumea, New Caledonia
5-12 July 2000

SCTB13 Working Paper

YFT–4

Updated CPUE of Central and Western Pacific Yellowfin Tuna from Taiwanese Tuna Fisheries.



Sun, C-L. & S-Z. Yeh

Institute of Oceanography, National Taiwan University,
Taipei, Taiwan, R.O.C.

Updated CPUE of Central and Western Pacific Yellowfin Tuna from Taiwanese Tuna Fisheries

Chi-Lu Sun and Su-Zan Yeh

Institute of Oceanography
National Taiwan University
Taipei, Taiwan, R.O.C.

Introduction

Taiwan's distant-water tuna longline vessels have been fishing in the Pacific Ocean since 1963. They primarily target albacore but also land significant numbers of yellowfin and bigeye tuna (Sun and Yeh 1992, 1993a, 1994, 1997, 1998a, 1998b, 1999). Taiwan's distant-water tuna purse seine vessels have been operating in the western Pacific since 1982, targeting mostly skipjack and yellowfin tuna (Sun and Yeh 1992, 1993b, 1994, 1997, 1998a, 1999). Taiwan's offshore tuna longline fleets based in the fishing ports of western Pacific Island countries have been fishing in the western Pacific since 1988. They target primarily yellowfin and bigeye tuna (Sun and Yeh 1998a, 1999).

The purpose of this paper is to update the standardized catch per unit effort (CPUE) series provided by Sun and Yeh (1999) for yellowfin tuna caught by the two distant-water fleets and the offshore longliners. 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 distant-water longline, purse seine, and offshore longline data for the periods 1964-1998, 1983-1999, and 1980-1999, respectively. The distant-water longline data were recently revised by OFDC by checking with the catch and effort information obtained from NMFS Honolulu Lab.

Materials and Methods

Distant-water longline fishery

Catch was expressed as number of fish taken and effort as number of hooks used by month and 5°x 5° square area during the period 1964-1998. The nominal CPUE value represented catch in number of yellowfin per 1000 hooks.

The detailed procedure for standardization of the Taiwanese distant-water longline CPUE using the general linear model (GLM) method (Kimura 1981, Allen and Punsly 1984, Draper and Smith 1981) 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.

The multiplicative model used in this analysis is

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

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*;
μ	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 non-peak);
ALB_m	is albacore catch rate *m*;
BET_n	is bigeye catch rate *n*;
interactions	is the two-way interactions among main effects except year;
ε_{ijklmn}	is the error term, NID $(0,\sigma^2)$.

Distant-water 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 1983-1999. 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.

The multiplicative model used in this analysis was

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

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;
μ	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 non-peak);
SKJ_n	is skipjack catch rate n;
interactions	is the two-way interactions among main effects except year;
ε_{ijklmn}	is the error term, NID(0,σ^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°x 5° square area during the period 1980-1999. The nominal CPUE value represented catch in number of yellowfin per 1000 hooks.

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

The multiplicative model used in this analysis was

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

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 bigeye catch rate l;
μ	is the overall mean;
Y_i	is year i;
M_j	is month j;

A_k	is WPYF area k;
BET_l	is bigeye catch rate l;
interactions	is the two-way interactions among main effects except year;
ε_{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 9,399. The frequency distribution of the standardized residuals for all variables combined effects was approximately close to that of the normal distribution (Figure 1a).

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 1. All of the main variables except for month, as well as the whole model are statistically significant ($p<0.01$). The fraction of sums of squares explained by the model (i.e. R^2) was 0.61.

Figure 1b shows the least square mean (LSM) estimates of annual CPUE (standardized CPUE) and the nominal CPUE. There is a downward trend of standardized CPUE during the period of 1964-1967. An increase is apparent during the 1968-1969 period, followed by a decrease in 1970 and an increase again in 1971. Another downward trend of standardized CPUE occurred during the period of 1971-1973. The CPUE maintained stable at the level of 3.0 fish per thousand hooks during the period of 1974-1980. The CPUE decreased to the level of 1.6 fish per thousand hooks during 1981-1984. The CPUE increased to the level of 2.1 fish per thousand hooks during 1985-1989. The CPUE decreased again to 1.2 fish per thousand hooks in 1989 and maintained stable thereafter at the level of 1.3 fish per thousand hooks with a slightly decreasing trend in recent five years.

The trend of nominal CPUE is similar although the standardized CPUE is generally lower than the nominal CPUE before 1981, and thereafter the standardized CPUE is generally slightly higher than the nominal CPUE .

Distant-water purse seine fishery

The total number of observations for this analysis was 3,491. The results of

ANOVA to examine the logged catch rate for differences among variables (year, month, set type, area, spawning season-area, and the catch rates of skipjack) are shown in Table 2. 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) was fairly low (0.22). The overall distribution of standardized residual (Figure 2a) was close to the normal curve.

Figure 2b shows the standardized and nominal annual CPUE. The standardized CPUE has increased since 1991 to a maximum of 5.3 mt per day in 1993. Afterward, the CPUE decreased sharply to the lowest level of 1.14 mt per day in 1996. The CPUE sharply increased to 4.41 mt per day in 1997. The CPUE decreased to the level of 2.5 mt per day in recent two years.

The nominal CPUE have similar trends although the nominal CPUE after 1992 is significantly higher.

Offshore longline fishery

The total number of observations for this analysis was 2,272. The results of ANOVA for the final model are shown in Table 3. The fraction of sum of squares explained by the model (i.e. R^2) was fairly low (0.31). The overall distribution of standardized residuals (Figure 3a) was close to the normal curve.

Figure 3b shows the standardized and nominal annual CPUE. The CPUE was high before 1986. There was an increasing trend from 1.9 to 5.52 fish per thousand hooks during the period of 1987-1996. The CPUE decreased to around 4 fish per thousand hooks in recent three years.

The trend of nominal CPUE is similar although after 1992 the nominal CPUE is higher than the standardized CPUE, especially in the years of 1992 and 1996.

The CPUE of yellowfin tuna for the offshore longline fishery was 3.1 times in average higher than for the distant-water longline fishery, primarily because the offshore longline fleet targets yellowfin tuna while the distant-water fleet targets albacore.

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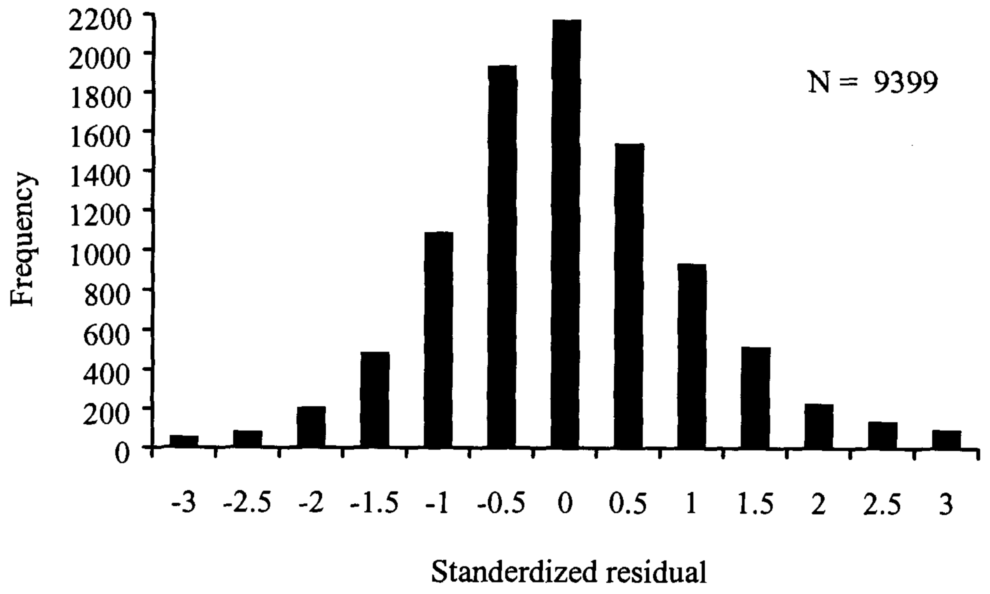

Figure 1a. Distribution of standerdized residuals of the models fitted to the yellowfin CPUE data from Taiwanese distant-water longline fishery in the western Pacific.

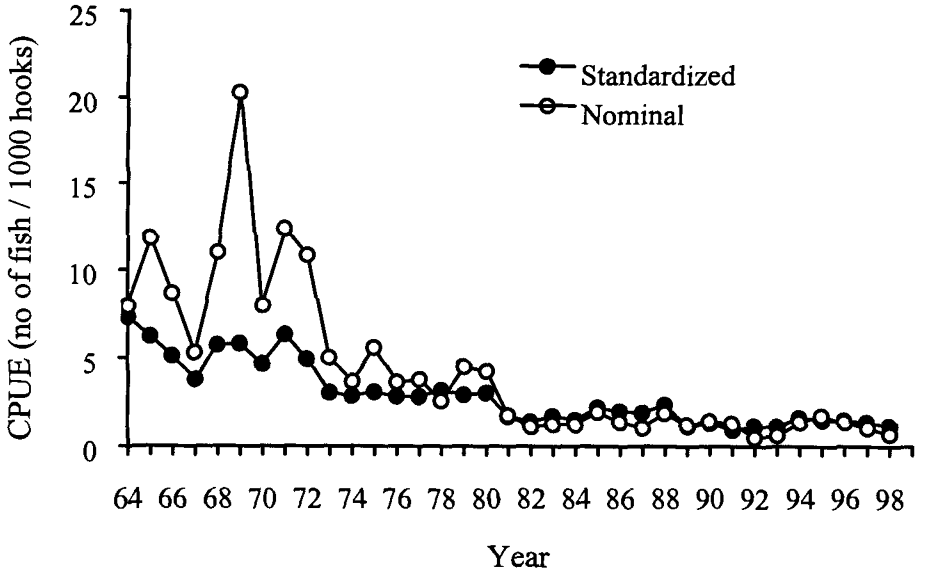

Figure 1b Standardized and nominal yellowfin CPUE for Taiwanese distant-water longline fishery in the western Pacific, 1964-1998.

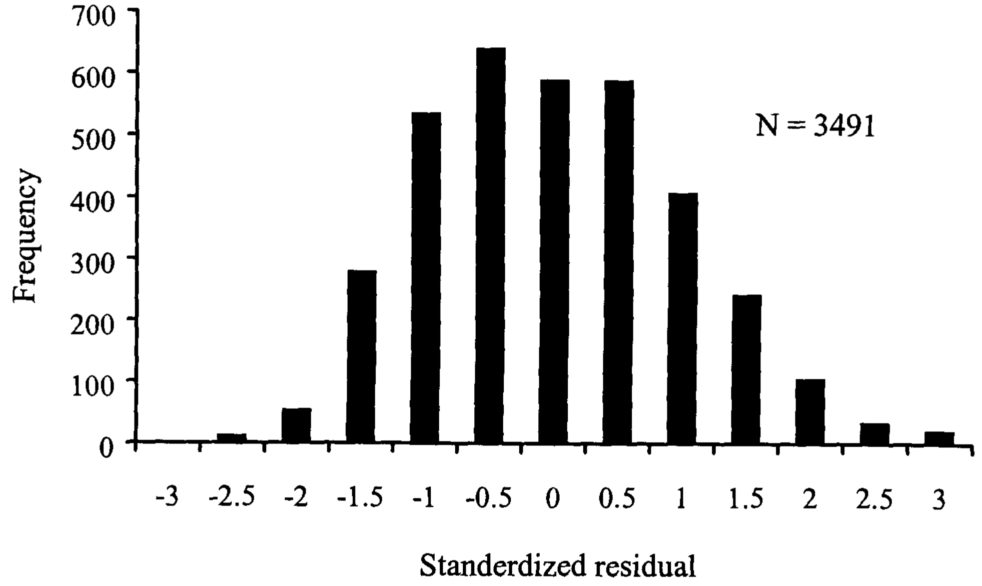

Figure 2a. Distribution of standerdized residuals of the models fitted to the yellowfin CPUE data from Taiwanese distant-water purse seine fishery in the western Pacific.

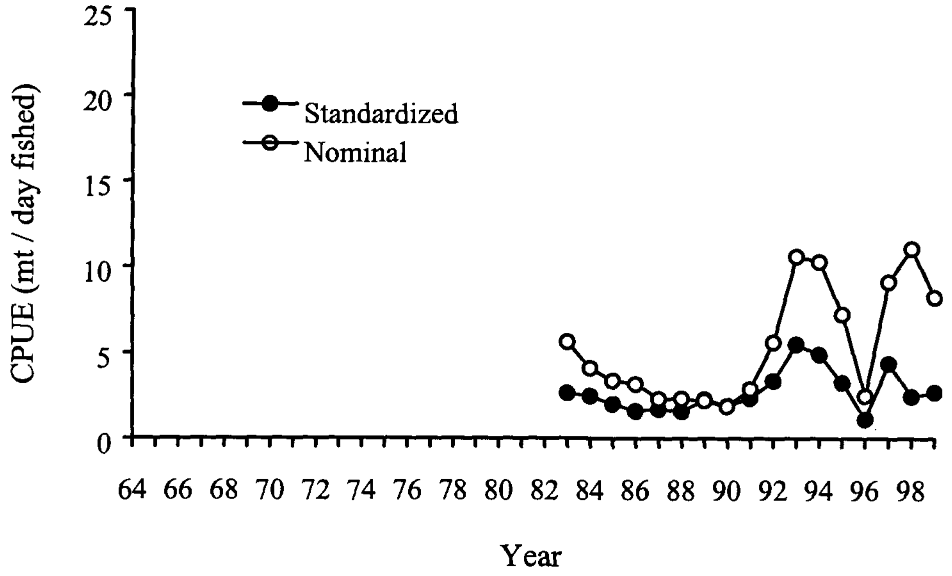

Figure 2b Standardized and nominal yellowfin CPUE for Taiwanese distant-water purse seine fishery in the western Pacific, 1983-1999.

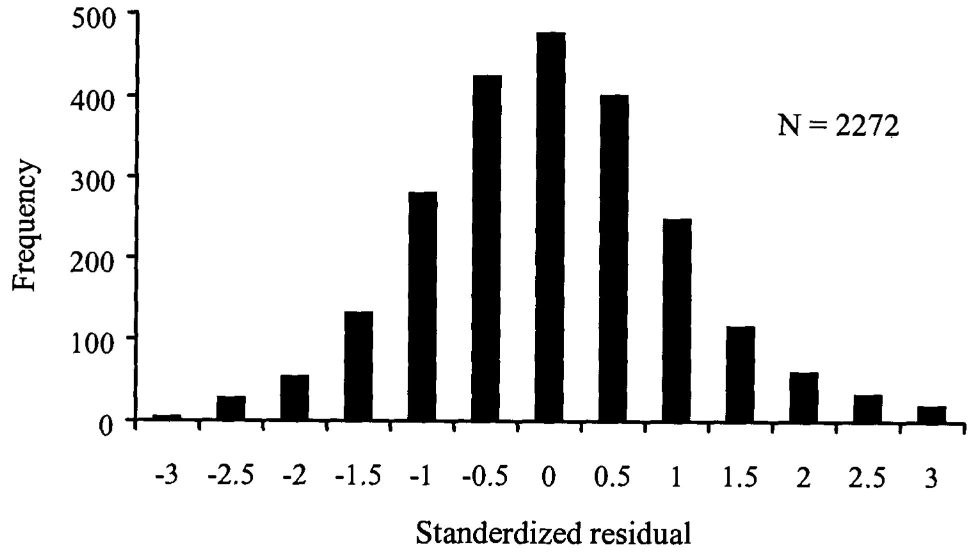

Figure 3a. Distribution of standerdized residuals of the models fitted to the yellowfin CPUE data from Taiwanese offshore longline fishery in the western Pacific.

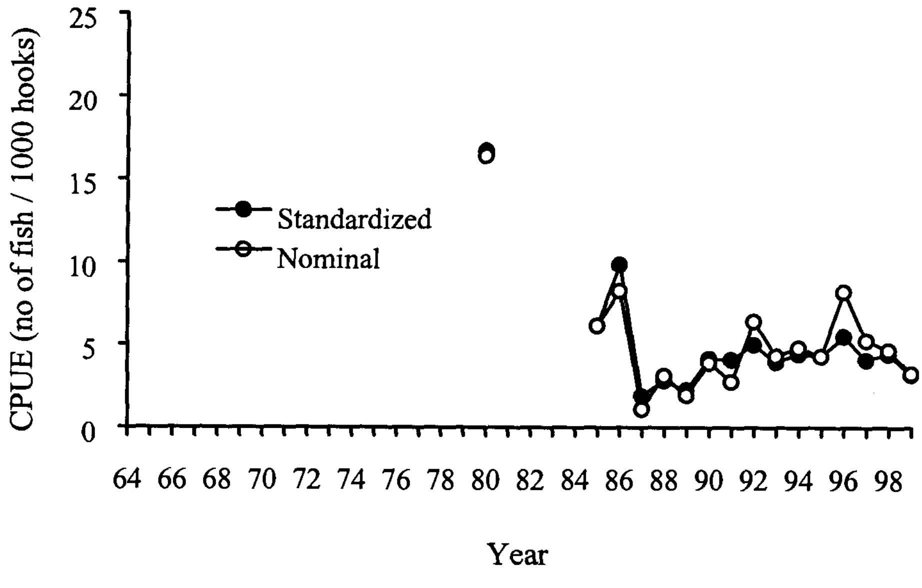

Figure 3b Standardized and nominal yellowfin CPUE for Taiwanese offshore longline fishery in the western Pacific, 1980-1999.

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

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Class Level Information

Class     Levels    Values

YEAR          35    1964 1965 1966 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 1997 1998
MONTH         12    1 2 3 4 5 6 7 8 9 10 11 12
AREA           7    1 2 3 4 5 6 7
SPAWN          2    N P
ALB            5    0 1 2 3 4
BET            5    0 1 2 3 4

Number of observations in data set = 9399

Dependent Variable: LNCPUE
                                     Sum of           Mean
Source                    DF        Squares         Square   F Value     Pr > F

Model                    254      5464.7668        21.5148     57.23     0.0001
Error                   9144      3437.3347         0.3759
Corrected Total         9398      8902.1015

                    R-Square           C.V.       Root MSE           LNCPUE Mean

                    0.613874       49.13979         0.6131                1.2477

Source                    DF    Type III SS    Mean Square   F Value     Pr > F

YEAR                      34      760.22728       22.35963     59.48     0.0001
MONTH                     11        3.40342        0.30940      0.82     0.6169
AREA                       6      487.59082       81.26514    216.18     0.0001
SPAWN                      1       26.21843       26.21843     69.75     0.0001
ALB                        4       55.87855       13.96964     37.16     0.0001
BET                        4       35.38093        8.84523     23.53     0.0001
MONTH*AREA                66      113.17237        1.71473      4.56     0.0001
MONTH*ALB                 44       69.17989        1.57227      4.18     0.0001
MONTH*BET                 44       35.52368        0.80736      2.15     0.0001
AREA*BET                  24       70.03547        2.91814      7.76     0.0001
ALB*BET                   16       24.05053        1.50316      4.00     0.0001
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Table 2. Analysis of variance results for the GLM model fitted to the yellowfin CPUE data from Taiwanese distant-water purse seine fishery.

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Class Level Information

Class     Levels    Values

YEAR          17    83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99
MONTH         12    1 2 3 4 5 6 7 8 9 10 11 12
SETTYPE        4    1 2 3 4
AREA           4    1 3 4 5
SPAWN          2    N P
SKJ            5    0 1 2 3 4

Number of observations in data set = 3491

Dependent Variable: LNCPUE
                                    Sum of            Mean
Source                   DF        Squares          Square   F Value     Pr > F

Model                    86     1088.04448        12.65168     10.98     0.0001
Error                  3404     3921.52541         1.15203
Corrected Total        3490     5009.56989

                   R-Square           C.V.        Root MSE          LNCPUE Mean

                   0.217193       88.32881         1.07333              1.21515

Source                   DF    Type III SS     Mean Square   F Value     Pr > F

YEAR                     16     310.973783       19.435861     16.87     0.0001
MONTH                    11      52.581841        4.780167      4.15     0.0001
SETTYPE                   3     170.470800       56.823600     49.32     0.0001
AREA                      3      50.404501       16.801500     14.58     0.0001
SPAWN                     1       5.704716        5.704716      4.95     0.0261
SKJ                       4      42.513124       10.628281      9.23     0.0001
MONTH*SETTYPE            33      62.665111        1.898943      1.65     0.0114
SETTYPE*SPAWN             3       9.973899        3.324633      2.89     0.0344
SETTYPE*SKJ              12      65.134798        5.427900      4.71     0.0001
```

Table 3. Analysis of variance results for the GLM model fitted to the yellowfin CPUE data from Taiwanese offshore longline fishery.

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Class Level Information

Class     Levels    Values

YEAR          16    1980 1985 1986 1987 1988 1989 1990 1991 1992 1993
                    1994 1995 1996 1997 1998 1999
MONTH         12    1 2 3 4 5 6 7 8 9 10 11 12
AREA           3    3 4 6
BET            4    1 2 3 4

Number of observations in data set = 2272

Dependent Variable: LNCPUE
                                      Sum of           Mean
Source                    DF         Squares         Square   F Value     Pr > F

Model                     92       367.73041        3.99707     10.40     0.0001
Error                   2179       837.79078        0.38448
Corrected Total         2271      1205.52120

                    R-Square            C.V.       Root MSE           LNCPUE Mean

                    0.305039        41.50253         0.6201                1.4940

Source                    DF     Type III SS    Mean Square   F Value     Pr > F

YEAR                      15       136.61492        9.10766     23.69     0.0001
MONTH                     11         6.73031        0.61185      1.59     0.0947
AREA                       2         2.86038        1.43019      3.72     0.0244
BET                        3         0.41831        0.13944      0.36     0.7800
MONTH*AREA                22        20.13962        0.91544      2.38     0.0003
MONTH*BET                 33        21.98693        0.66627      1.73     0.0061
AREA*BET                   6        23.87438        3.97906     10.35     0.0001
```