Standardized CPUEs of Central and Western Pacific Yellowfin Tuna from Taiwanese Distant-Water 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 (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). 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).

The purpose of this paper is to provide standardized catches per unit effort (CPUEs) for yellowfin tuna caught in the central and western Pacific by the two fleets mentioned above. The standardized CPUEs 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 CPUEs of the longline and purse seine data for the periods 1967-1992 and 1983-1993, 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 1967-1992. 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, and spawning season-area.

The multiplicative model which was used last year was used again this year. The model is

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

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 spawning season-area l,
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 nonpeak), and
ε_{ijkl}	is the error term, $N(0,\sigma)$.

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 fishing. These variables were presented by month in a 5°x 5° square area (as opposed to the 2°x 5° area used last year) during the period 1983-1993. 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 (new effect added, compared to last year's), and spawning season-area.

The multiplicative model, PS1, used in this analysis is

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

where

ln	is the natural logarithm,
$CPUE_{ijklm}$	is the nominal catch rate (MT/day) in year i, month j, WPYF area k, set type l, and spawning season-area m,
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 nonpeak), and
ε_{ijklm}	is the error term, $N(0,\sigma)$.

Data preparation and calculation employing SAS Statistical Software, Version 6.04, were performed on PC and HP850 computers.

Results and Discussion

Taiwanese longline fishery

The total number of observations for this analysis is 7,282. The frequecny 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, and spawning season-area) are shown in Table 1. 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 0.50.

Figure 2 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 1978-1979 period, followed by a decrease during 1980-1982. The CPUE is fairly stable from 1983 to 1988, and from 1989 to 1992, the level maintains a low, stable condition.

Figure 3 illustrates the comparison between the CPUE values during the peak spawning season and area and non-peak spawning season and area. After three years of its lowest values during 1989-1991, the CPUE value of non-peak spawning season and area rises in 1992 to a level close to that of 1988.

There is no peak spawning season and area data in 1992 for the Taiwanese longline fishery. Therefore, we cannot update 1992's CPUE in the peak spawning season and area for that fishery. This lack of data could possibly be due or related to a poor coverage rate of the Taiwanese longline data or a shifting of the fishing grounds of the Taiwanese longline fleets. Further confirmation is needed in this regard.

Taiwanese purse seine fishery

The total number of observations for this analysis is 1,563. 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 2. The remaining three variables (year, month, and set type) 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 (0.22). The overall distribution of standardized residual (Figure 1B) is close to the normal curve.

Figure 4 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 4.6 MT per day in 1993.

In order to improve the above model (PS1), which has a relatively low R^2, the two-way interactions of the three main variables were considered for further analysis. The new model, PS2, was

$$\ln(CPUE_{ijk}+1) = \mu + Y_i + M_j + S_k + Y_iM_j + Y_iS_k + M_jS_k + \varepsilon_{ijk}$$

The results of ANOVA are ahown in Table 3. Although the "month" variable is statistically insignificant ($p>0.05$), its interactions with the "set type" and "year" variables are significant ($p<0.05$). Therefore, "month" is retained in the model.

The R^2 of this model (0.37) is higher than that of the model which did not include the interaction terms. The combined distribution of the standardized residuals is close to that of a normal distribution (Figure 1C).

The LSM estimates of annual CPUE and their associated relative 95% confidence limits are shown in Figure 5. In this data set, LSM estimates adjusted for the three significant interactions are not possible for 1983-1985 due to missing data in this period. Also in Figure 5 the 95% confidence limits of the standardized CPUE are wide in 1992 and 1993 compared to the other years of this model as well as PS1.

The trend of the estimates of the CPUEs from both models are consistent with each other. The CPUE values in PS1 during 1986-1989, however, are greater than those of PS2, while the situation in all other years is reversed. In 1993, the values of both models are similar.

Since the adoption of PS2 model would result in the loss of the CPUE values for 1983-1985 as mentioned before, we finally decide to adopt the PS1 model.

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. 708pp.

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. 1992. Taiwan's yellowfin tuna fisheries in the central and western Pacific Ocean. Working Document WPYRG2/10.

Sun, C.L. and S.Z. Yeh. 1993a. Standardized catch rates of yellowfin tuna (*Thunnus albacore*) from the Taiwan tuna longline fishery in the central and western Pacific Ocean. Working Document WPYRG3/11.

Sun, C.L. and S.Z. Yeh. 1993b. Trend of abundance index of yellowfin tuna from Taiwan purse seine fishery in the central and western Pacific Ocean. Working Document WPYRG3/12.

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

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YEAR	26	67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92
MONTH	12	1 2 3 4 5 6 7 8 9 10 11 12
AREA	5	3 4 5 6 7
SPAWN	2	N P

Number of observations in data set = 7282

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	41	3585.96025172	87.46244516	174.01	0.0
Error	7240	3639.07549243	0.50263474		
Corrected Total	7281	7225.03574414			

	R-Square	C.V.	Root MSE	LNCPUE Mean
	0.496324	53.43437	0.70896737	1.32680037

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	25	1650.45677197	66.01827088	131.34	0.0
MONTH	11	230.63053968	20.96641270	41.71	0.0001
AREA	4	1478.75865012	369.68966253	735.50	0.0
SPAWN	1	226.11428995	226.11428995	449.86	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	25	946.82587545	37.87303502	75.35	0.0
MONTH	11	43.87771793	3.98888345	7.94	0.0001
AREA	4	1322.21700101	330.55425025	657.64	0.0
SPAWN	1	226.11428995	226.11428995	449.86	0.0001

Table 2. Analysis of variance results for the GLM model (PS1) fitted to the yellowfin CPUE from Taiwan purse seine fishery.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
SETTYPE	4	1 2 3 4
YEAR	11	83 84 85 86 87 88 89 90 91 92 93
MONTH	12	1 2 3 4 5 6 7 8 9 10 11 12

Number of observations in data set = 1563

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	395.75900825	16.48995868	17.82	0.0001
Error	1538	1423.17028489	0.92533829		
Corrected Total	1562	1818.92929314			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.217578	89.48947	0.96194505	1.07492537

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SETTYPE	3	162.60764976	54.20254992	58.58	0.0001
YEAR	10	199.64900616	19.96490062	21.58	0.0001
MONTH	11	33.50235233	3.04566839	3.29	0.0002

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SETTYPE	3	97.60753941	32.53584647	35.16	0.0001
YEAR	10	204.03929850	20.40392985	22.05	0.0001
MONTH	11	33.50235233	3.04566839	3.29	0.0002

Table 3. Analysis of variance results for the GLM model (PS2) fitted to the yellowfin CPUE from Taiwan purse seine fishery.

General Linear Models Procedure
Class Level Information

Class	Levels	Values
SETTYPE	4	1 2 3 4
YEAR	11	83 84 85 86 87 88 89 90 91 92 93
MONTH	12	1 2 3 4 5 6 7 8 9 10 11 12

Number of observations in data set = 1563

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	186	671.49042702	3.61016359	4.33	0.0001
Error	1376	1147.43886613	0.83389452		
Corrected Total	1562	1818.92929314			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.369168	84.95271	0.91317825	1.07492537

Source	DF	Type I SS	Mean Square	F Value	Pr > F
SETTYPE	3	162.60764976	54.20254992	65.00	0.0001
YEAR	10	199.64900616	19.96490062	23.94	0.0001
MONTH	11	33.50235233	3.04566839	3.65	0.0001
SETTYPE*YEAR	26	95.66702162	3.67950083	4.41	0.0001
SETTYPE*MONTH	33	39.54675167	1.19838641	1.44	0.0526
YEAR*MONTH	103	140.51764547	1.36424899	1.64	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SETTYPE	3	8.34158389	2.78052796	3.33	0.0188
YEAR	10	69.12767596	6.91276760	8.29	0.0001
MONTH	11	11.31138659	1.02830787	1.23	0.2594
SETTYPE*YEAR	26	82.88178435	3.18776094	3.82	0.0001
SETTYPE*MONTH	33	42.16746290	1.27780191	1.53	0.0279
YEAR*MONTH	103	140.51764547	1.36424899	1.64	0.0001

```
FREQUENCY                                                      TWLL
                                                             (N=7282)
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

                                                             TWPS
                                                             PS1 model
 300 +                          ***                          (N=1563)
     |                          ***
 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

                                                               TWPS
     |                               ***                     PS2 model
 300 +                               ***                     (N=1563)
     |                               ***  ***
     |                               ***  ***
     |                          ***  ***  ***
     |                     ***  ***  ***  ***
 200 +                     ***  ***  ***  ***
     |                     ***  ***  ***  ***  ***
     |                     ***  ***  ***  ***  ***
     |                     ***  ***  ***  ***  ***
     |                ***  ***  ***  ***  ***  ***
 100 +                ***  ***  ***  ***  ***  ***
     |                ***  ***  ***  ***  ***  ***  ***
     |                ***  ***  ***  ***  ***  ***  ***
     |           ***  ***  ***  ***  ***  ***  ***  ***  ***
     |      ***  ***  ***  ***  ***  ***  ***  ***  ***  ***  ***  ***
    -------------------------------------------------------------------
       -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) Taiwan longline fishery (B and C) Taiwan purse seine fishery in the western Pacific, respectively.

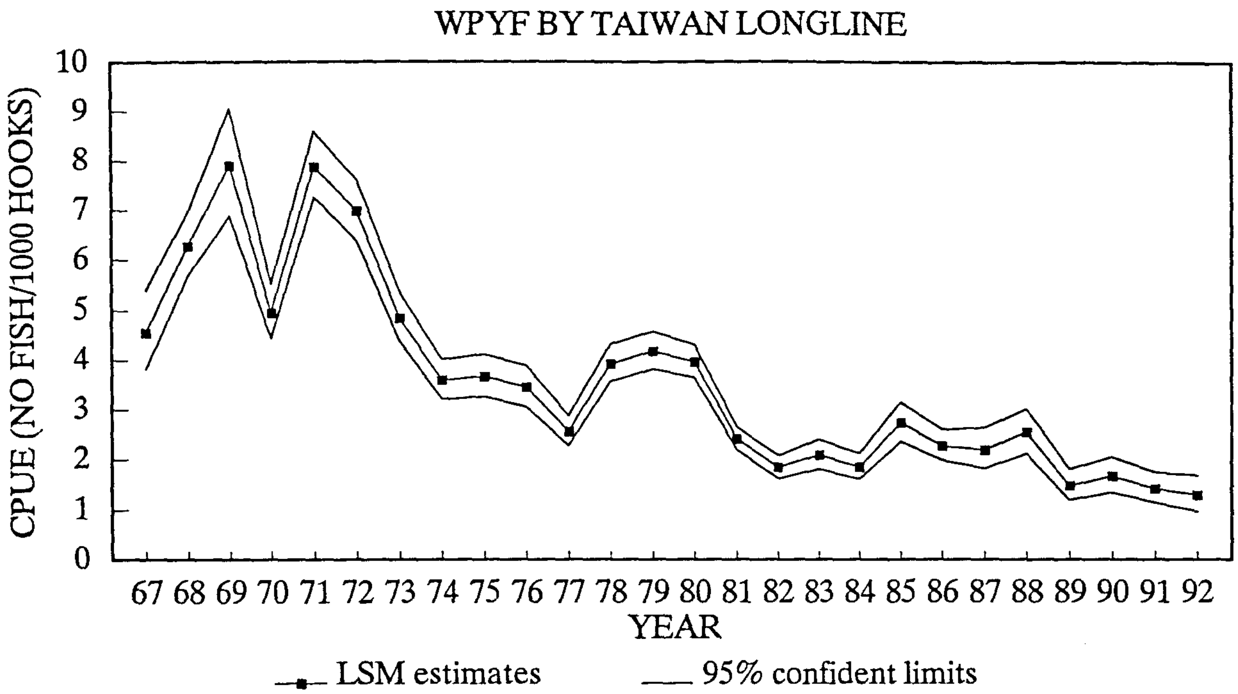

Figure 2. Least square mean estimates and 95% confidence limits of standardized yellowfin CPUE for Taiwan longline fishery in the western Pacific, 1967-92.

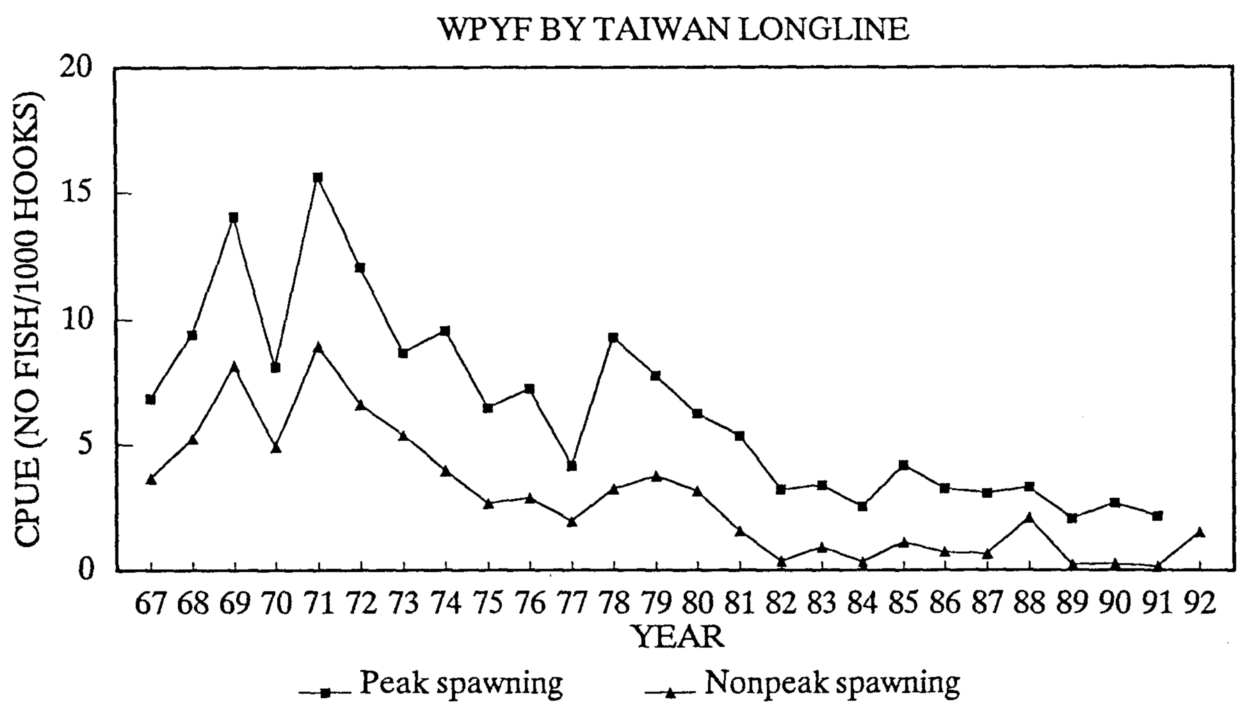

Figure 3. Standardized CPUE (number of fish per 1000 hooks) of yellowfin tuna by peak and nonpeak spawning season and area for Taiwan longline fishery in the western Pacific, 1967-92.

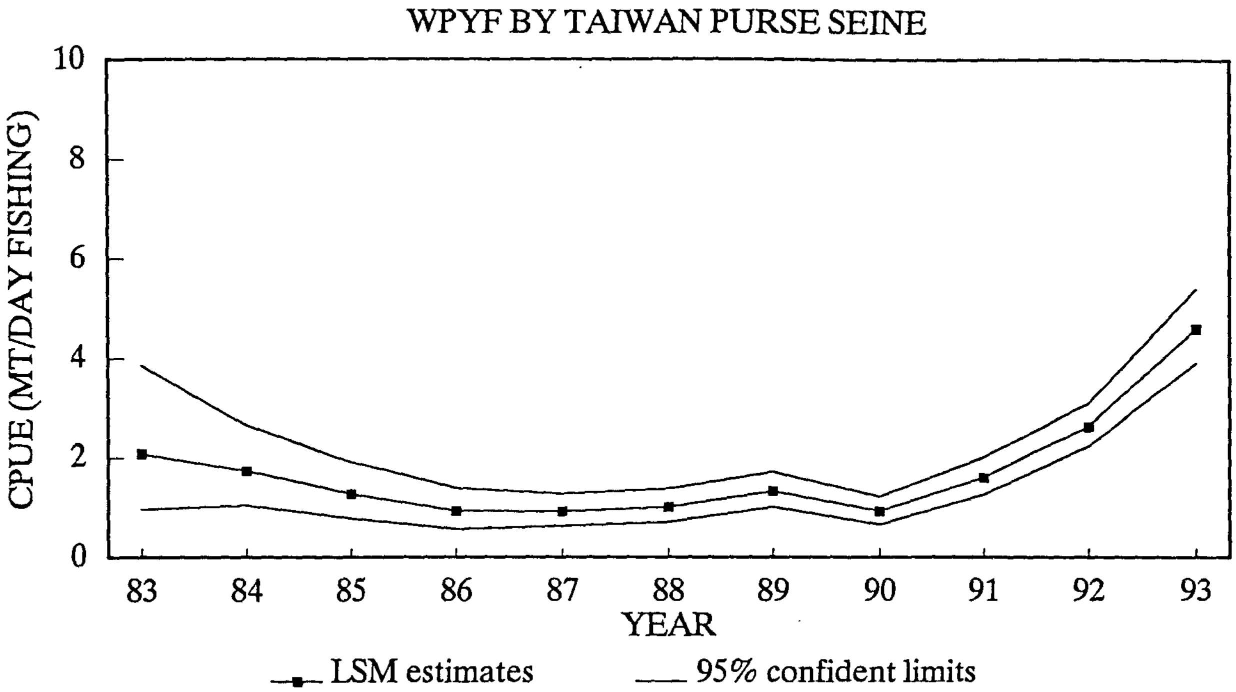

Figure 4. Least square mean estimates and 95% confidence limits of standardized yellowfin CPUE for Taiwan purse seine fishery in the western Pacific, 1983-92. (estimated from PS1 model)

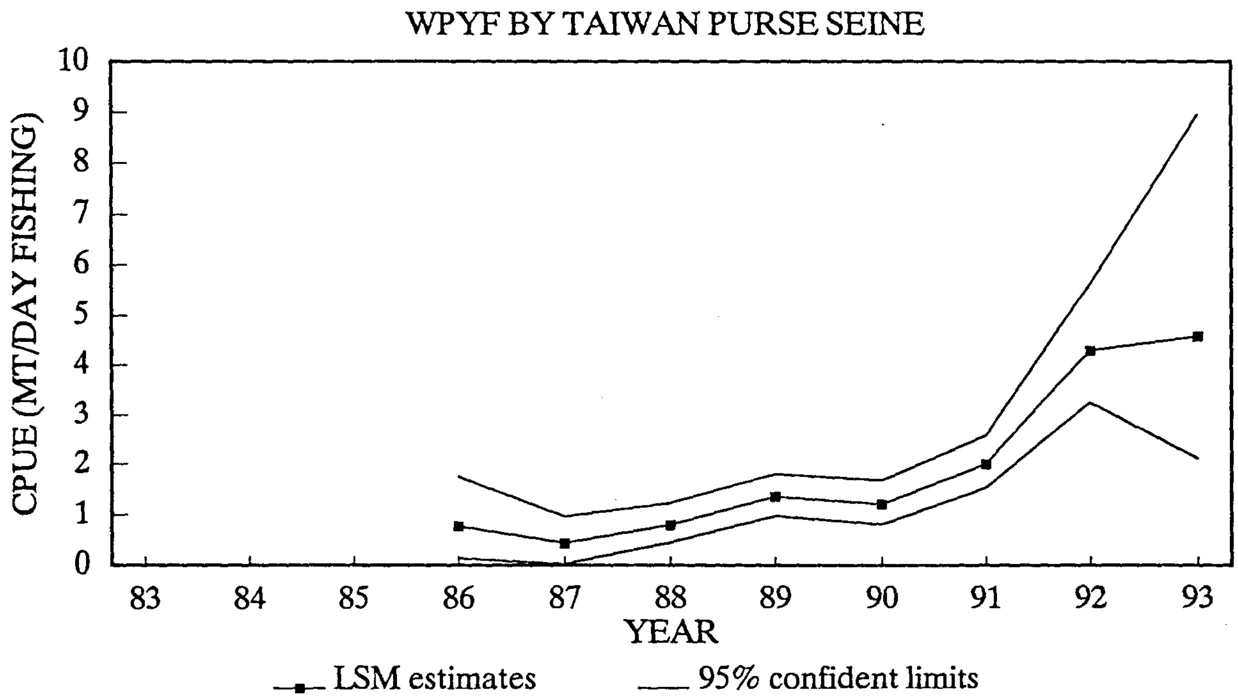

Figure 5. Least square mean estimates and 95% confidence limits of standardized yellowfin CPUE for Taiwan purse seine fishery in the western Pacific, 1986-92. (estimated from PS2 model)