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INTRODUCTION

Taiwan distant-water tuna purse seine, or Taiwan purse seine, vessels have been operating in the western Pacific Ocean since 1982 and the target species is the skipjack (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacore*) (Sun and Yeh, 1992).

The yellowfin abundance index series from CPUE estimates based on adjusted catches was reported by Tsuji (1990) for Japanese purse seine fishery. SPC (1990) compared the Japanese purse seine yellowfin CPUE data in the area 10°N-10°S and 130°E-180°E with the data stratified into area of 2° latitude by 5° longitude, either monthly or quarterly. However, the abundance trends using Taiwan purse seine data have not been analyzed previously.

In this paper, the generalized linear models (GLM's) (Draper and Smith, 1981; Kimura, 1981, Robin and Punsly, 1984) were used to estimate the annual (1983-1992) catch rates of yellowfin based on Taiwan purse seine data collected by SPC. The result provide a preliminary description of the pattern or trends of yellowfin tuna abundance in the central and western Pacific Ocean.

MATERIAL AND METHOD

The data were presented as catch, the tonnage of fish caught and effort, the number of fishing plus searching days used in an area 2°x5° square per month during the period from 1983 to 1992. The nominal CPUE value represents catch in tonnage of yellowfin per day. The main variable chosen to implement the GLM analyses were year, month, area and peak spawn season-area. The data were stratified into area of either 2^{o} latitude by 5^{o} longitude or WPYF-3 and WPYF-4.

Peak spawn season-area was between November-April in the western equatorial region (10^{o}N-5^{o}S, 130^{o}-170^{o}E) and March-September in central equatorial region (10^{o}N-10^{o}S, 180^{o}-120^{o}W) as described by Sakagawa (1992).

To facilitate the estimation of parameters, the interaction of the main variables were omitted and the multiplicative model was reduced to

$$LN(CPUE+1) = \mu + Y_i + M_j + A_k + A_l + P_m + \varepsilon_{ijklm}$$

where

- Ln: Natural logarithm
- CPUE: Nominal CPUE (catch in metric tons per day) in year i, Month j, Area k and peak spawn season-area l
- μ : overall mean
- Y_i: year i
- M_j: month j
- A_k: WPYF area k
- A_l: 2^{o}x5^{o} area l
- P_m: peak or non-peak spawn season-area
- ε_{ijklm}: error term, N $(0, \sigma)$

F-tests were conducted on all main variables to determine whether or not each contributed significantly to the model. At the conclusion of each GLM run, the least significant variable was omitted and the new model was tested again. This process was repeated until all remaining variables contributed significantly to the model. The frequency distribution of the standard residuals, (observed - predicted) / standard error of the estimate, were examined at each level of main variables and for whole model to ensure that they approximated the normal distribution. The final model was used to develop standardized catch rates for each year.

RESULT AND DISCUSSION

The total number of observations for this analysis was 1740, and the number of observations for each main variable were shown in Table 1. The frequency distribution of the standardized residuals for individual variable as well as for their combined effect are shown in Fig. 1. The combined distribution of the standardized residuals is close to that of a normal distribution. In some cases, the distribution of the normalized residuals of individual variable differs from that of the normal.

The results of using GLM analysis of variance (ANOVA) to examine logged catch rate for difference among the variable of years, months, WPYF areas and $2^{\circ} \times 5^{\circ}$ areas are shown in Table 2. A value of 1 was added to the nominal CPUE values to treat zero catches. In all main variables model are statistical significant.

Estimated CPUE and nominal CPUE are shown in Fig. 2. There is a downward trend of CPUE's after 1983 and reach a minimum of 0.21 MT per day in 1989. Thereafter the CPUE value increased gradually; In 1992, the CPUE was 1.33 MT per day.

Figs. 3 and 4 show the trend of the adjusted CPUE and nominal CPUE in areas WPYF-3 and WPYF-4 respectively. In general, the trend of CPUE in WPYF-4 is similar to that of WPYF-3, but the CPUE value in WPYF-4 is larger than that of WPYF-3, except in the year 1989. furthermore, the lowest CPUE value occurred in 1987 in WPYF-3 while it occurred in 1989 for WPYF-4 area. Overall, the trend of CPUE based on Taiwan's purse seine data differs from CPUE's trend conducted by Tsuji (1990) and SPC (1990), even if the fishing area examined is similar. Further study will be needed to reconcil the discrepancy.

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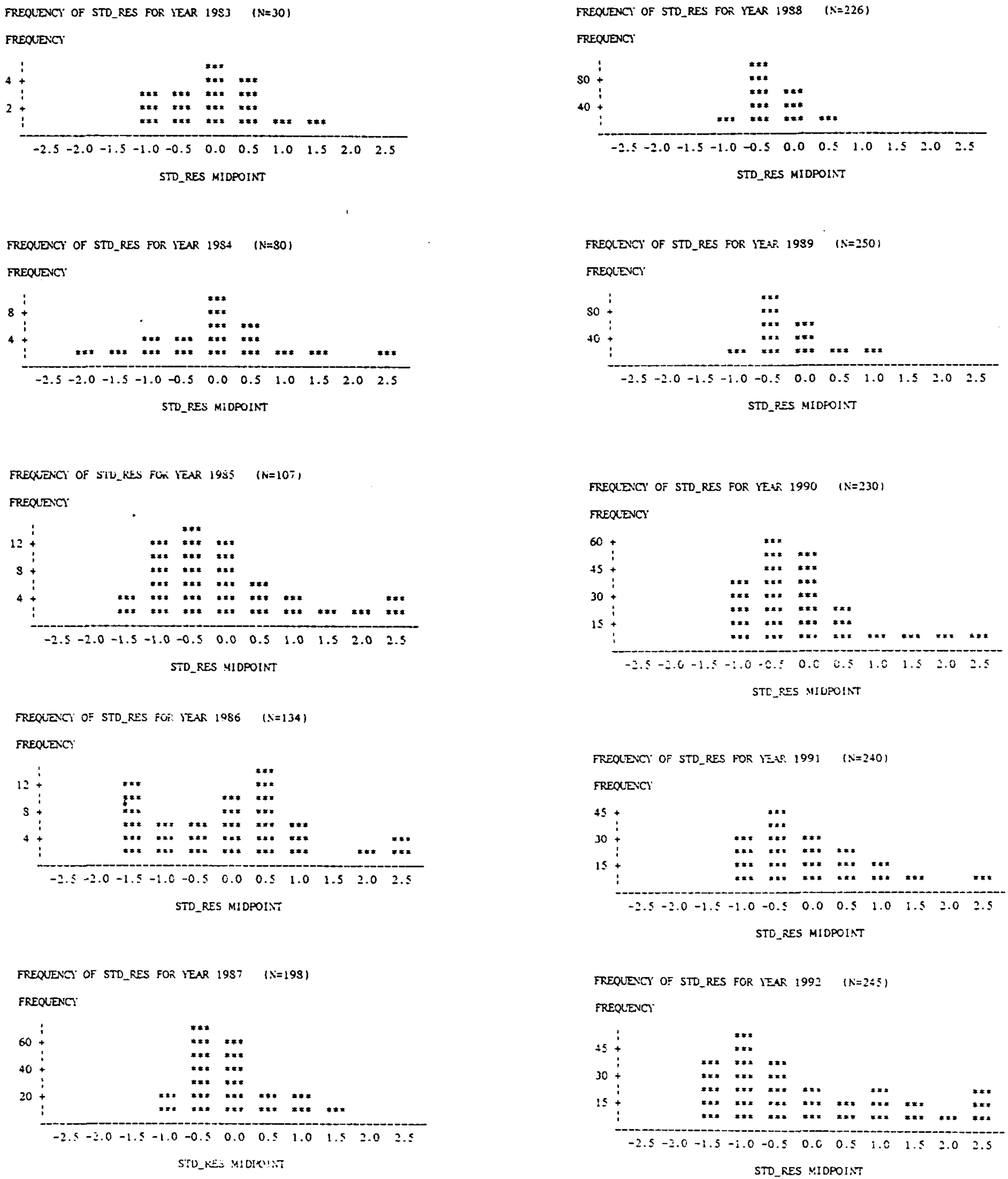

Fig. 1-1. Distributions of standardized residuals at each level of year tested in the GLM procedure.

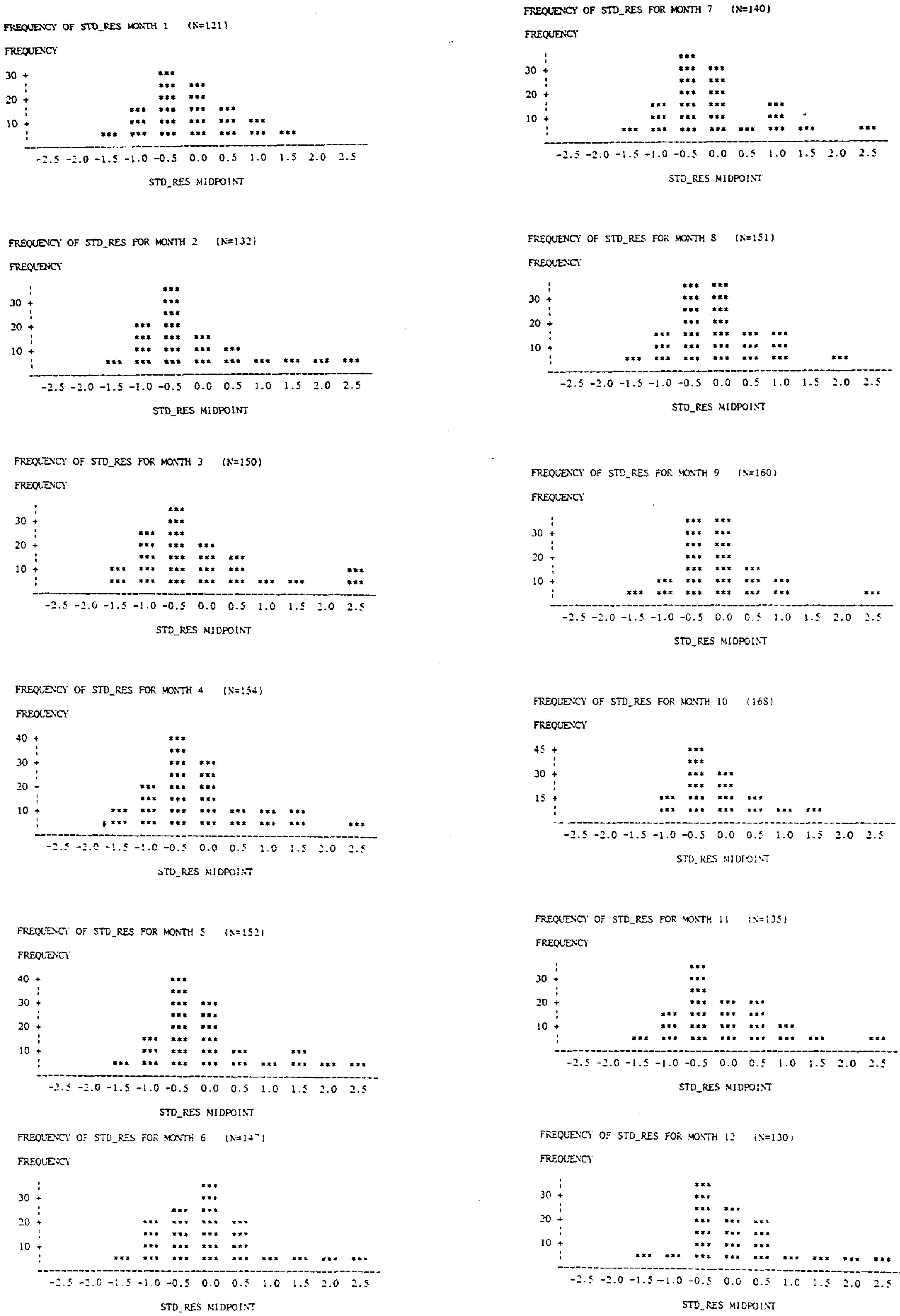

Fig. 1-2. Distributions of standardized residuals at each level of month tested in the GLM procedure.

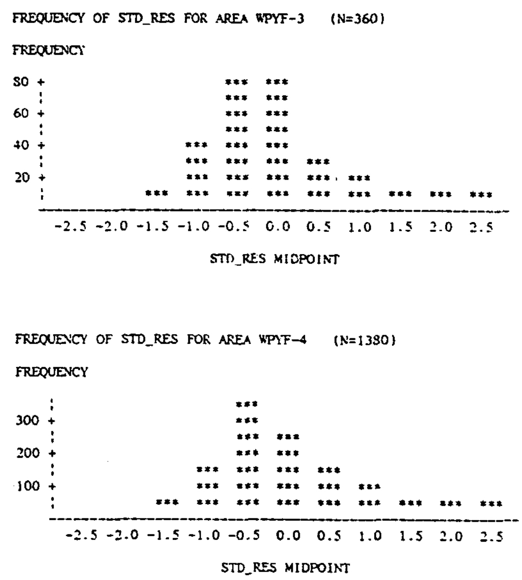

Fig. 1-3. Distributions of standardized residuals at each level of area tested in the GLM procedure.

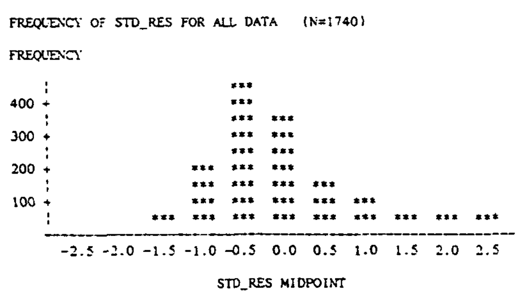

Fig. 1-4. Distributions of standardized residuals of the final model determined using the GLM procedure.

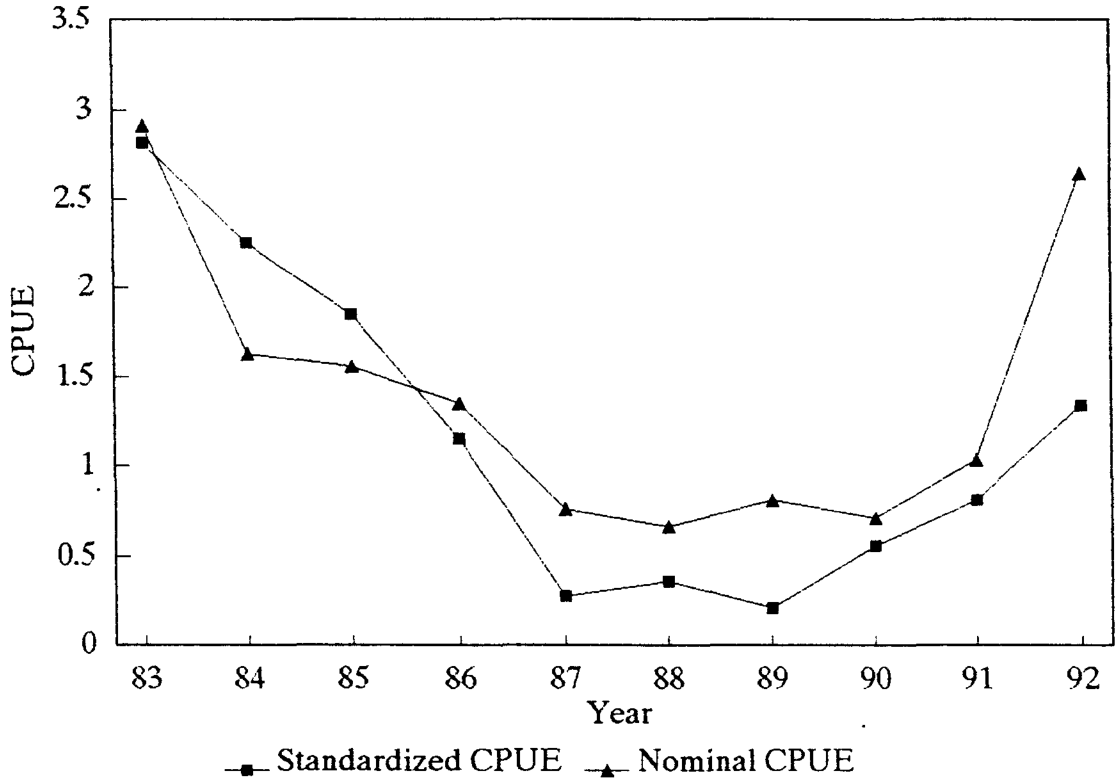

Fig. 2. Standardized and nominal CPUE (MT/day) of yellowfin tuna for Taiwan purse seine fishery in the central and western Pacific, 1983-1992.

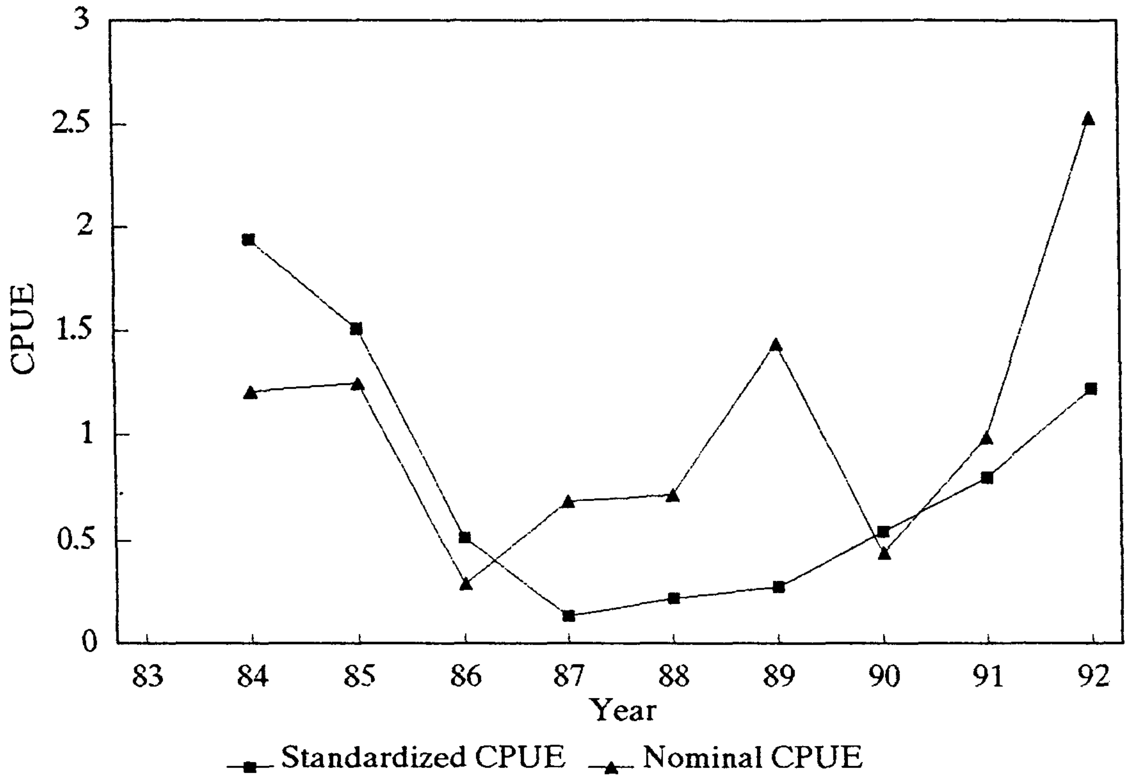

Fig. 3. Standardized and nominal CPUE (MT/day) of yellowfin tuna for Taiwan purse seine fishery in area WPYF-3 of the central and western Pacific, 1983-1992.

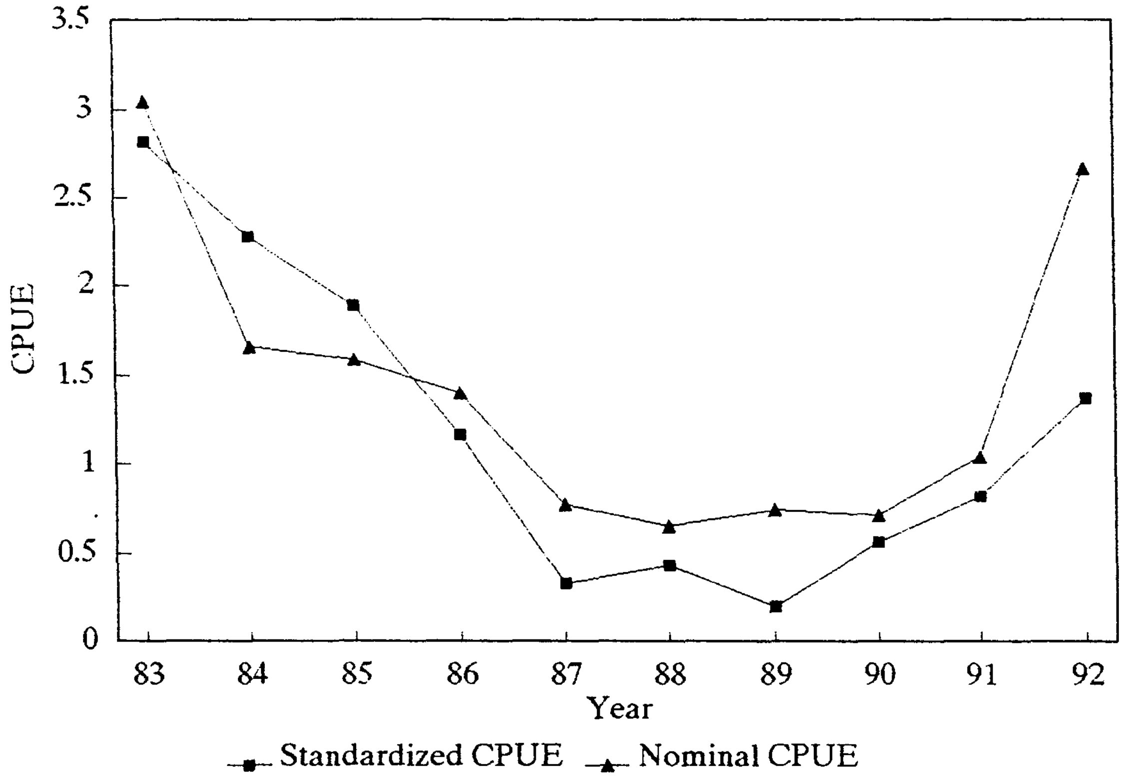

Fig. 4. Standardized and nominal CPUE (MT/day) of yellowfin tuna for Taiwan purse seine fishery in area WPYF-4 of the central and western Pacific, 1983-1992.

Table 1. Number of observations for each main variable in the final model.

Year	No. of obs.	Month	No. of obs.	WPYF area	No. of obs.
Y83	30	M1	121	WPYF-3	360
Y84	80	M2	132	WPYF-4	1380
Y85	107	M3	150		
Y86	134	M4	154		
Y87	198	M5	152		
Y88	226	M6	147		
Y89	250	M7	140		
Y90	230	M8	151		
Y91	240	M9	160		
Y92	245	M10	168		
		M11	135		
		M12	130		

2X5AREA	No. of obs.	2X5AREA	No. of obs.	2X5AREA	No. of obs.	2X5AREA	No. of obs.
A11	12	A21	14	A31	10	A41	18
A12	12	A22	30	A32	41	A42	60
A13	45	A23	50	A33	74	A43	120
A14	14	A24	33	A34	59	A44	95
A15	5	A25	12	A35	33	A45	57
A16	3	A26	8	A36	17	A46	32
A17	-	A27	4	A37	2	A47	11
A18	-	A28	1	A38	2	A48	4
A51	14	A61	5	A71	2	A81	-
A52	51	A62	24	A72	3	A82	-
A53	125	A63	73	A73	35	A83	3
A54	94	A64	74	A74	50	A84	20
A55	65	A65	46	A75	24	A85	9
A56	42	A66	26	A76	23	A86	6
A57	16	A67	10	A77	5	A87	7
A58	3	A68	5	A78	2	A88	0

Table 2. Analysis of variance results for GLM model fitted to Taiwan purse seine yellowfin CPUE data.

General Linear Models Procedure

Dependent Variable: LNCPUE

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	79	142.52252548	1.80408260	5.35	0.0001
Error	1358	457.90761525	0.33719265		
Corrected Total	1437	600.43014073			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.237367	120.6394	0.58068291	0.48133769

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	9	93.48508007	10.38723112	30.81	0.0001
MONTH	11	7.09265177	0.64478652	1.91	0.0340
SPCAREA	1	5.97544360	5.97544360	17.72	0.0001
D2X5AREA	58	35.96935005	0.62016121	1.84	0.0002

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	9	79.62671243	8.84741249	26.24	0.0001
MONTH	11	7.68683592	0.69880327	2.07	0.0196
SPCAREA	1	2.84358716	2.84358716	8.43	0.0037
D2X5AREA	58	35.96935005	0.62016121	1.84	0.0002