STANDARDIZED CPUE FOR YELLOWFIN TUNA CAUGHT BY THE TAIWANESE LONGLINE FISHERY IN THE INDIAN OCEAN, 1967-1996.

Lee, Y.-C.[1]

ABSTRACT

The yearly nominal CPUE and standardized CPUE based on the catch and effort data of Taiwanese longline fishery using a GLM indicates that the stock of yellowfin tuna decreased gradually from 1968 to 1979. However, since 1979, the stock status has almost been maintained stable.

Introduction

Industrial and artisanal fisheries have exploited Indian Ocean yellowfin tuna since the 1950s. The industrial fisheries include longline and purse seine fisheries. The total catches of all fisheries were several thousand tonnes from 1952 to 1982 but have increased markedly since 1983 and have ranged from one hundred thousand tonnes to four hundred thousand tonnes (Figure 1). Japanese industrial longliners have exploited yellowfin tuna since 1952, Taiwanese longliners since 1954, and Korean longliners since 1966. New entrants since the 1980s include Indian, Indonesian and Sri Lankan industrial longliners.

Yellowfin tuna is an important target species for the Taiwanese longline fishery in the Indian Ocean. The catch of the Taiwanese longline fishery has ranged from 3,300 to 88,000 tonnes from 1971 to 1996 (Table 1). The catch and effort data for Indian Ocean yellowfin tuna for the Taiwanese longline fishery was little used to study stock dynamics except for the western sub-stock by Nishida (1995).

The time-series of catch per unit effort (CPUE) for tunas seems to be appropriate for use as an abundance index for assessing the stock (Hsu, 1996; Uosaki, 1996). Moreover, the Generalized Linear Model (GLM) has been used to assess the tuna stock status as presented in many international expert fora in recent years. These include CCSBT for southern bluefin tuna and ICCAT for albacore, yellowfin and bigeye tuna, etc.

There have many hypotheses about sub-stocks of Indian Ocean yellowfin tuna, i.e., two sub-stocks (Kikawa *et al.*, 1970; Morita and Koto, 1970; Huang *et al.*, 1973), three sub-stocks (Kurogane and Hiyama, 1958), and four sub-stocks (Nishida, 1992). However, this study considers a single stock as well as western and eastern two major sub-stock hypotheses (Nishida, 1992).

In the IPTP Expert Consultation in 1993, the CPUE value for the Korean longline fishery was the highest, followed by the Japanese longline fishery, while the Taiwanese longline fishery the lowest. After standardization, the CPUE trends indicate constant yellowfin tuna apparent abundance (IPTP, 1995). Therefore, this study addresses separately the stock status of a single stock and two major sub-stocks using the GLM method based on the Taiwanese longline fishery data only.

Materials and methods

The catch and effort data, compiled from the vessel logbooks recovered is by month and by 5^o x 5^o area from 1967 to 1996. The unit of catch per unit effort used is catch in numbers per 10^3 hooks.

The boundaries of two major sub-stocks, followed by Nishida (1992) are shown in Figure 2. In this study, the main factors of year, quarter, aggregated areas as well as the percentages catch rate of albacore and bigeye tunas are used in the GLM model. The multiplicative GLM model selected is as follows:

$$log(cpue+ c) = \mu + year+ quarter+ area+ alb+ bet+ \varepsilon$$

Where μ is the overall mean, ε is an error term assumed as a normal distribution with zero mean and σ^2, and the aggregated areas are selected according to the distribution of nominal CPUE of yellowfin tuna. The percentage catch rates of albacore and bigeye tunas are divided into five intervals. The constant c is adopted to fit the model. In this study, the constant c, adopted was 10 % nominal CPUE, is recommended by the CCSBT CPUE/VPA workshop from Dr. T. Nishida (Anon, 1996; Campbell, *et al.*, 1996).

Results and Discussion

This study first computed the yearly nominal CPUE of the Taiwanese longline fishery from 1967 to 1996 (Figure 3). The CPUE trend in the early history of the fishery had the highest values from 1967 to 1977. Then, the lowest values from 1978 to 1985. After 1986, the CPUE increased again. The CPUE for this period seems to be higher than that of 1978-1985, but still lower than that of 1967-1977. This study, therefore, divided the exploited history of Taiwanese longline fishery into three stages, i.e., the highest CPUE stage in 1967-1977, the lowest CPUE stage in 1978 -1985, and the mid CPUE stage in 1986-1996. Then, this study combined all catch and effort data during these three stages to graph 5° x 5° area distributions of nominal effort (Figs. 4, 5, 6) and nominal CPUE (Figs. 7, 8, 9). The nominal effort distribution in 1967-1977 show that Taiwanese longliners operated mainly in two areas, i.e., between 5°N – 40°S and 40°E – 65°E as well as between 15°N – 20°S and 80°E – 105°E. From 1978 to 1985, they mainly operated between 15°N - 10°S and 75°E - 100°E, and South of 15°S. In 1986-1996, they mainly operated North of 10°S and between 30°S – 40°S and 35°E - 100°E, as well as in the area surrounding Madagascar.

The nominal CPUE distribution in 1967-1977 show a higher density of yellowfin tuna mainly aggregated North of 15°S. From 1978 to 1955, the CPUE distribution was generally lower. Most CPUEs were lower than 2.5 individuals/10^3 hooks, except the area near the equator and the area of the

[1] Institute of Fisheries Science, National Taiwan University , #1, Section 4, Roosevelt Road, Taipei 106, Taiwan.

north-eastern Indian Ocean. From 1986 to 1996, a higher density appeared clearly to the North of 10°N area and in the area near the equator.

There were different fishing patterns for the three stages. Therefore, this study divided the Indian Ocean into eight aggregated areas (Figure 10). The areas were adopted as the area factors in the GLM model to resolve targeted species and fishing gear differences for the Taiwanese longline fishery.

The statistics of the GLM analysis are shown in Table 2. All factors show significance and in the model explain 0.569741, 0.480595, and 0.476153 for the overall, western, and eastern stocks, separately (R^2 = 0.569741, 0.480595, and 0.476153). The histograms of standardized residuals from GLM fitting show likely normality as assumed in the model (Figure 11). The standardized CPUE, lower and upper 95 % confidence limits are shown in Figure 12. All the three CPUE trends have the highest values in 1968, and gradually decrease to 1979. Since 1979, the CPUE trends have almost remained stable. Besides, there was little difference between the two limits and standardized CPUE in 1967-1978. However, the two limits and standardized CPUE were almost the same after 1978.

The comparisons of the nominal and standardized CPUE are shown in Figure 13. The nominal CPUEs are higher than the standardized CPUEs in the 1968-1972 period and in 1986-1996 for the western and overall stocks. Conversely, the nominal CPUE is lower than the standardized CPUE in 1967 and from 1973 to 1985. However, the nominal CPUE is higher than the standardized CPUE in the periods of 1967-1972, 1975-1977, and 1979-1996 for the eastern stock. However, the nominal CPUE is lower than the standardized CPUE in the period of 1973-74 and in 1976.

Therefore, this study concludes that the stock status of yellowfin tuna decreased gradually from 1968 to 1979. However, since 1979, the stock status has almost remained stable. Moreover, this study supposes that (1) the history of the Taiwanese longliners mainly targeted yellowfin tuna in 1967-1978. From the mid 1970s, they gradually transferred targeting to albacore (Lee and Liu, 1993) rather than yellowfin tuna. However, since 1986, many new so-called deep longliners (Huang, 1995) have mainly caught bigeye tuna and yellowfin tuna, but albacore has still been a targeted species for the Taiwanese regular longliners; and (2) the Indian yellowfin tuna maybe just have one unit stock.

Acknowledgment

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Table 1: Yearly catch of Indian Ocean yellowfin tuna of the Taiwanese longline fishery from 1971 to 1996.

Year	Catch (tonnes)
1971	11840
1972	11840
1973	5702
1974	4397
1975	4630
1976	3355
1977	8079
1978	4245
1979	3704
1980	3806
1981	4101
1982	4715
1983	5580
1984	5812
1985	7321
1986	16249
1987	22365
1988	22765
1989	22425
1990	31638
1991	30713
1992	55988
1993	88026
1994	33984
1995	23069
1996	27850

Table 2. Analysis of variance for overall, western, and eastern stocks.

Overall					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	11019.25	234.45	448.31	0.0001
Error	15912	8321.55	0.52		
Corrected Total	15959	19340.80			
	R-Square	C.V.	Root MSE	CPUE Mean	
	0.57	15:04	0.72	0.89	
YEAR	29	3117.37	107.50	205.55	0.0001
QUARTER	3	14.79	4.93	9.43	0.0001
AREA	7	1449.30	207.04	395.90	0.0001
ALB	4	447.15	111.79	213.75	0.0001
BET	4	72.64	18.16	34.73	0.0001
Western					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	47	4828.81	102.74	197.05	0.0001
Error	10009	5218.76	0.52		
Corrected Total	10056	10047.57			
	R-Square	C.V.	Root MSE	CPUE Mean	
	0.48	16:49	0.72	1.25	0.0001
YEAR	29	2090.04	72.07	138.22	0.0002
QUARTER	3	10.43	3.48	6.67	0.0001
AREA	7	712.31	101.76	195.16	0.0001
ALB	4	308.95	77.24	148.13	0.0001
BET	4	18.07	4.52	8.67	0.0001
Eastern					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	44	2884.77	65.56	129.09	0.0001
Error	6249	3173.72	0.51		
Corrected Total	6293	6058.49			
	R-Square	C.V.	Root MSE	CPUE Mean	
	0.48	19:02	0.71	1.12	
YEAR	29	1380.29	47.60	93.72	0.0001
QUARTER	3	13.48	4.49	8.85	0.0001
AREA	4	445.99	111.50	21954	0.0001
ALB	4	20.49	5.12	10.09	0.0001
BET	4	43.46	10.87	21.39	0.0001

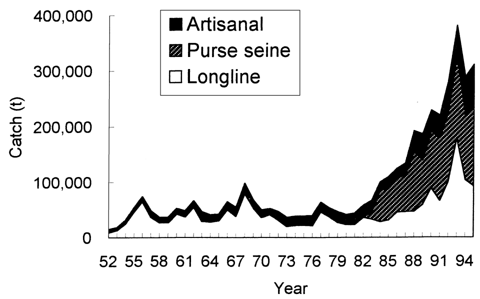

Figure 1. Yearly catch of Indian Ocean Yellowfin tuna for longline, purse seine and artisanal fisheries from 1952 to 1995. (data source: IPTP data summary no.17)

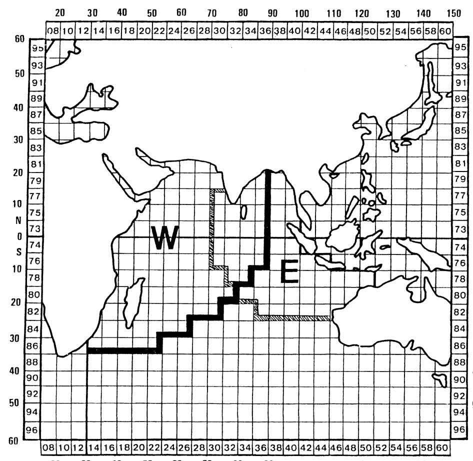

Figure 2. The boundary of Western and eastern sub-stocks (after Nishida, 1992).

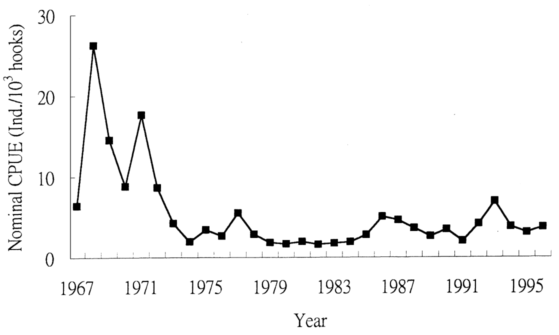

Figure 3. Nominal CPUE of Indian yellowfin tuna for Taiwanese longline fishery, 1967-1996.

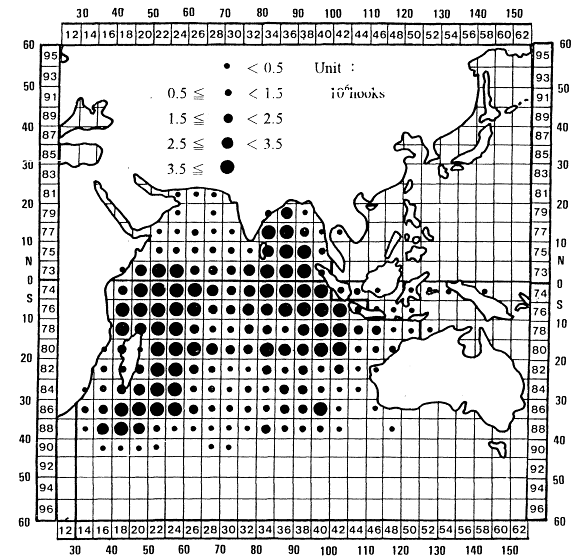

Figure 4. The Nominal effort distribution of averaging 5° X 5° area for Indian yellowfin tuna by Taiwanese longline fishery in 1967-1977.

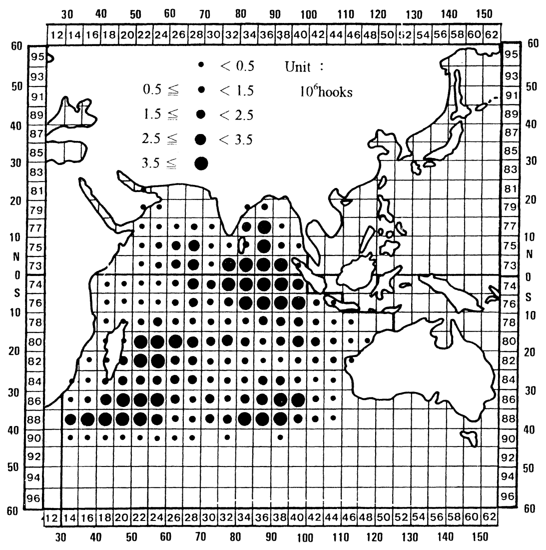

Figure 5. The nominal effort distribution of averaging 5° X 5° area for Indian Ocean yellowfin tuna by Taiwanese longline fishery in1978-1985.

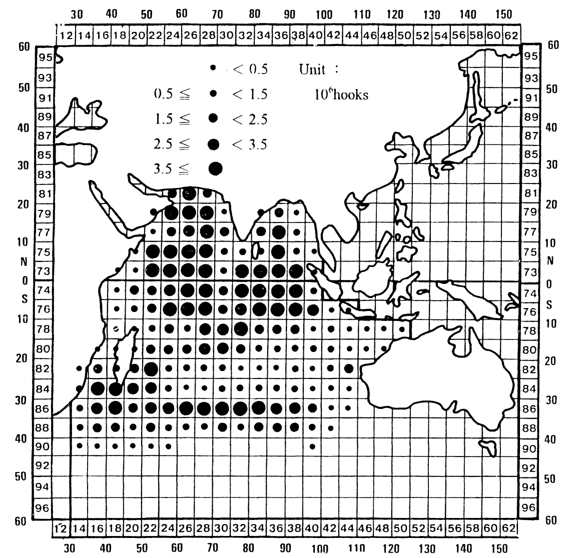

Figure 6. The nominal effort distribution of averaging 5° X 5° area for Indian Ocean yellowfin tuna by Taiwanese longline fishery in 1986-1996.

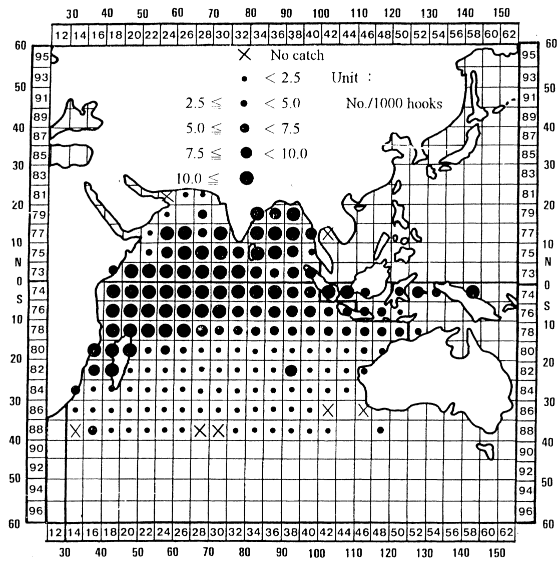

Figure 7. The nominal catch per unit effort (CPUE) distribution of averaging 5° X 5° area for Indian Ocean yellowfin tuna by Taiwanese longline fishery in 1967-1977.

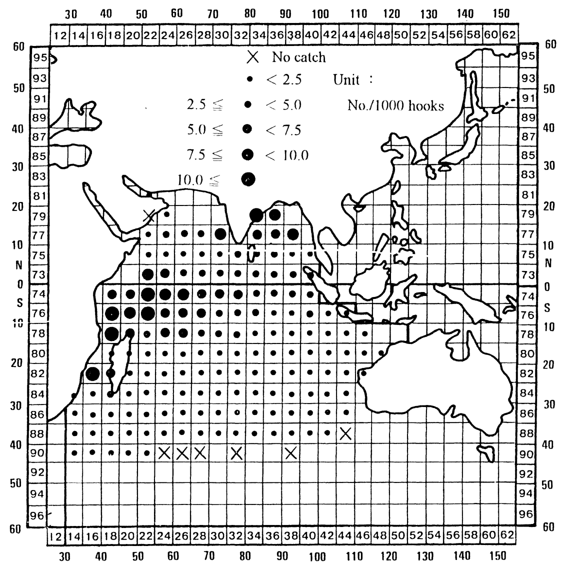

Figure 8. The nominal catch per unit effort (CPUE) distribution of averaging 5° X 5° area for Indian Ocean yellowfin tuna by Taiwanese longline fishery in 1978-1985.

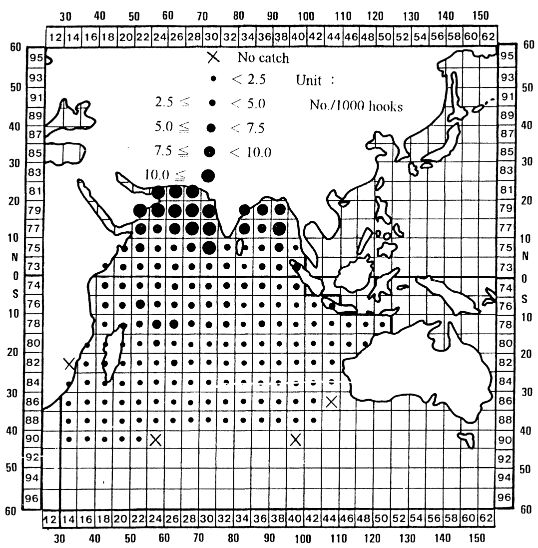

Figure 9. The nominal catch per unit effort (CPUE) distribution of averaging 5° X 5° area for Indian Ocean yellowfin tuna by Taiwanese longline fishery in 1986-1996.

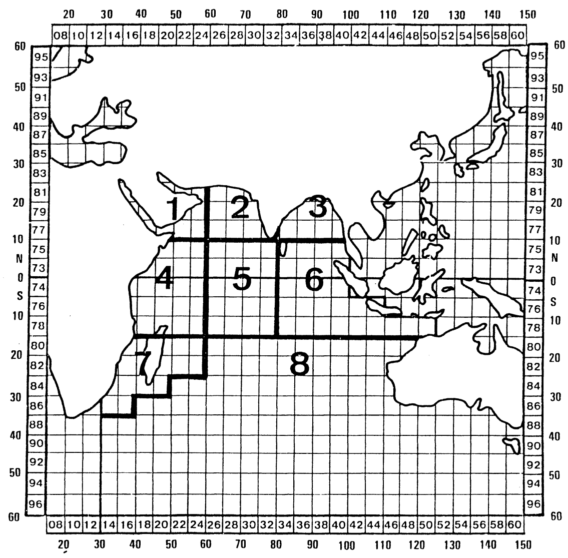

Figure 10. Sub-area used in the standardization of CPUE using GLM model for Indian Ocean yellowfin tuna in 1967-1996.

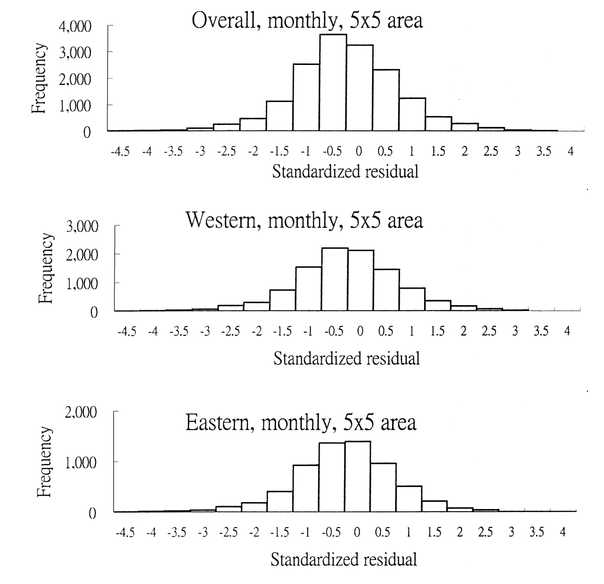

Figure 11. The histogram of standardized residuals from fitting GLM for showing the normality of standardizing Taiwanese longline fishery for yellowfin tuna in the Indian Ocean, 1967-1996.

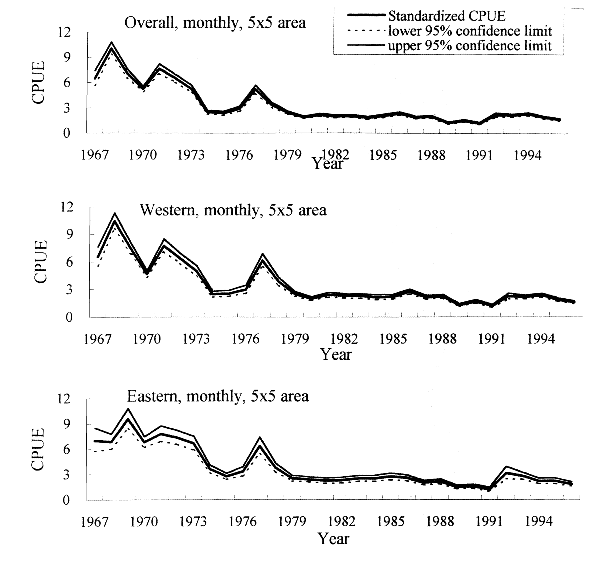

Figure 12. Standardized CPUE of Indian yellowfin tuna using GLM Taiwanese longline fishery, 1967-1996.

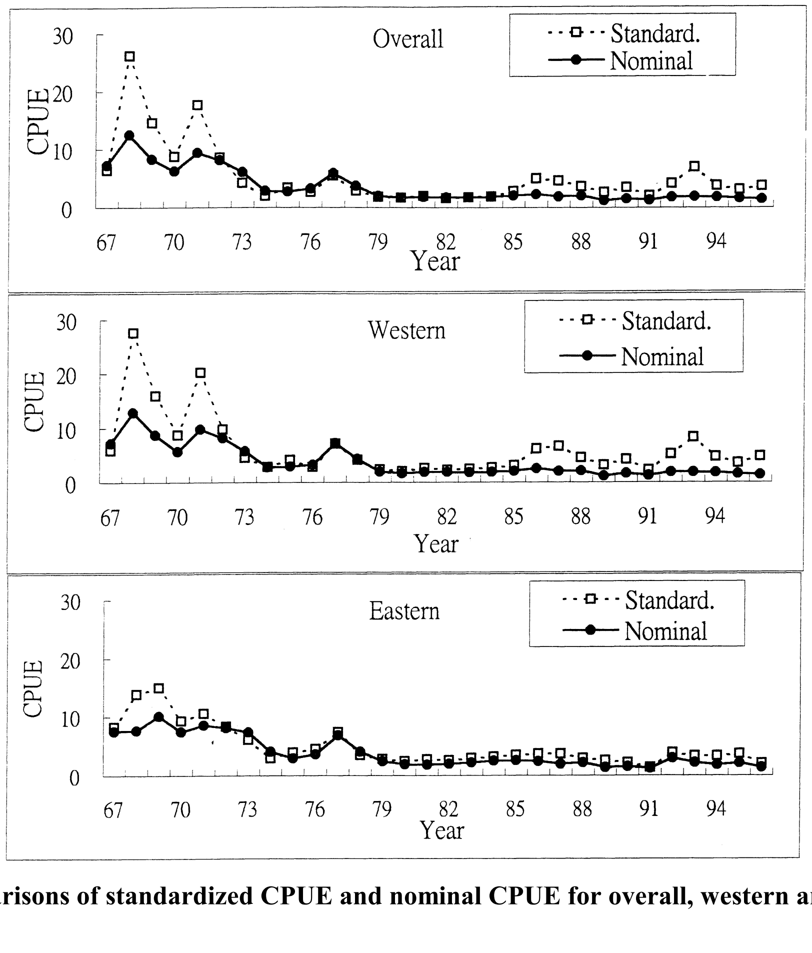

Figure 13. Comparisons of standardized CPUE and nominal CPUE for overall, western and eastern stocks.