STANDARDIZED CPUE FOR YELLOWFIN TUNA CAUGHT BY THE TAIWANESE LONGLINE FISHERY IN THE INDIAN OCEAN, 1967-1998

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ABSTRACT

This study analyzed the catch and effort data of Taiwanese Iongline fishery. The standardized CPUE using GLM method was adopted to investigate the stock status. The result show that the CPUE trends in 1968 for the Whole stock has the highest value, and gradually decreases to 1979. Since 1979, the CPUE trend almost has maintained at a stable status. Under the two major sub-stocks hypothesis, the CPUE trends of the Western and Eastern stocks are very like the Whole stock, i.e., the three CPUE trends are similar.

Therefore, this study suggests that the yellowfin tuna stock has maintained at a stable status since 1979. And the Indian yellowfin tuna maybe just have one unit stock, based on the continuing fishing area and density distribution as well as the similar CPUE trends for the three stocks.

INTRODUCTION

Industry and artisanal fisheries have exploited Indian yellowfin tuna since

1950's. The industry fisheries include longline and purse seine fisheries. The total catches of all fisheries were several thousand tons only from 1952 to 1982. Since 1983, the total catches have strictly increased and have ranged from one hundred thousand tons to four hundred thousand tons (Fig. 1, Table 1). Concerning industry longline fisheries, Japanese longliners have exploited yellowfin tuna since 1952, Taiwanese longliners since 1954, and Korean longliners since 1966 as well as most new involving industry longliners including Indian, Indonesian and Sri Lanka's, etc. since 1980's.

Yellowfin tuna is one of the important targeted species for Taiwanese longline fishery in the Indian Ocean. The catch of Taiwanese longline fishery ranged 3,300 – 88,000 tons from 1971 to 1998. The catch and effort data of Indian yellowfin tuna for Taiwanese Iongline fishery was few used to study stock dynamic except Nishida (1995) and Lee (1998).

The time series of catch per unit effort (CPUE) for tunas seems to be appropriately used as 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 in many international expert conferences in recent years, for example CCSBT for southern bluefin tuna and ICCAT for albacore, yellowfin and bigeye tuna, etc.

There have many hypotheses about sub-stocks of Indian 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 is under just one stock as well as Western and Eastern two major sub-stocks hypotheses (Nishida, 1992).

In expert consultation of IPTP in 1993, the CPUE value of Korean longline fishery was the highest, Japanese longline fishery next, and Taiwanese longline fishery the lowest. After standardization, the CPUE trends indicate constant yellowfin tuna apparent abundance (IPTP, 1995).

In expert consultation of IOTC in 1998, the consultation concluded that the status of the stock is currently unknown.

Therefore, this study intends to separately respond stock status of just one stock and two major sub-stocks using GLM method based on Taiwanese longline fishery data only.

MATERIALS AND METHODS

The catch and effort data sets of Taiwanese Iongline fishery in the Indian Ocean used in this study is monthly and 5º x 5º area from 1967 to 1998. The boundary of two major sub-stocks, followed by Nishida (1992) is shown in Fig. 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 selected in the GLM model. The multiplicative GLM model selected is as follows:

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

Where μ is overall mean, e is error term assumed as normal distribution with zero mean and S^2 and the aggregated areas are selected according to the distributions of nominal effort and nominal CPUE of yellowfin tuna. The percentages catch rate of albacore and bigeye tunas are divided into five intervals. The constant c is adopted as 10% nominal CPUE (Anon, 1996; Campbell, et aI., 1996).

RESULTS AND DISCUSSION

This study firstly computed the yearly nominal CPUE of Taiwanese longline fishery from 1967 to 1998 (Fig. 3). The CPUE trend of yellowfin tuna showed that in early history of the fishery had the highest values from 1967 to 1977. Then, it had the lowest values from 1978 to 1985. After 1986, the CPUE increased again, and then, it gradually decreased to 1991. From 1992, it increased again to 1993, after that, it decreased gradually to 1998. The CPUE of this period seems to be higher than that of 1978-1985 but still lower than that of 1967-1977. Therefore, this study briefly divided the exploited history of Taiwanese longline fishery into four stages, i.e., the highest CPUE stage in 1967-1977, the lowest CPUE stage in 1978-1985, and the mid CPUE stage in 1986-1991 as well as 1992-1998. Then, this study combined all catch and effort data during these four stages to graph 5º x 5º area distribution of nominal effort (Figs. 4, 5, 6, 7) and nominal CPUE (Figs. 8, 9,10,11). The nominal effort distribution in 1967-1977 showed that Taiwanese Iongliners operated mainly at two group areas, i.e., between 5º N 40º S and 40º E - 65º E as well as between 15º N - 20º S and 80º E - 105º E. In 1978-1985, they mainly operated between l5^0 N - 10^0 S and 75^0 E - 100^0 E, and southern of l5^0 S. In 1986-1991, they mainly operated in northern of 15º S, and between 30^0 S - 40º S and 30ºE - 100º E. In 1992-1998, they operated almost all the Indian Ocean.

The nominal CPUE distribution in 1967-1977 showed that the higher density of yellowfin tuna mainly aggregated at northern of 15º S. In 1978-1985, the CPUE distribution was lower generally. Most CPUEs were lower than 2.5 individuals/10^3 hooks except the area near equator and the area at the northeastern Indian Ocean. In 1986-1991 and 1992-1998, the CPUE distribution was similar. The higher density clearly appeared at the northern of 100 N area; the moderate density appeared between 10 º N and 15º S area, however, southern of 15º 5 area had lowest density.

In sum, there had different fishing patterns for the four stages. Therefore, this study divided the whole Indian Ocean into five aggregated areas (Fig. 12). The first area and second area have the highest density. The third area has the next higher density. The fifth area has the lowest density. Nevertheless, the density of the fourth area is between the third and fifth area. These areas will be adopted as the area factors in GLM model to respond times, targeted species, and fishing gear differences for the Taiwanese longline fishery.

The statistics of GLM analysis are shown in Table 2. All factors show significance as well as those factors in the model explain 0.465, 0.463, and 0.462 for the Whole, Western, and Eastern stock, separately (R^2 =0.465, 0.463, and 0.462). The histograms of standardized residuals from fitting GLM show likely normality as assumed in the models (Fig. 13). The standardized CPUE, lower 95% confidence limit, and upper 95% confidence limit are shown in Fig. 14. The CPUE trends in 1968 for the Whole stock has the highest value, and gradually decreases to 1979. Since 1979, the CPUE trend almost has maintained at a stable status. Under the two major sub-stocks hypothesis, the CPUE trends of the Western and Eastern stocks are very like the Whole stock, i.e., the three CPUE trends are similar. Besides, there has a little distance among the two limits and standardized CPUE in 1967-1978. However, the two limits and standardized CPUE are almost the same after 1978.

The comparison of the nominal CPUE and standardized CPUE is shown in Fig. 15. It shows that the nominal CPUE is higher than the standardized CPUE each year for the Whole stock. The pattern of Western stock is similar to the Whole stock, i.e., the former is higher than the latter each year. The pattern of the Eastern stock is also similar to the Whole stock in most years, however, the latter is higher than the former in 1973-1974, 1978 and 1991-1992.

Therefore, this study suggests that the yellowfin tuna stock has maintained at a stable status since 1979. And the Indian yellowfin tuna maybe just have one unit stock, based on the continuing fishing area and density distribution as well as the similar CPUE trends for the three stocks.

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Table 1. The yearly catch of Indian yellowfin tuna for the area 5l and 57, 1950-1997.

Year	F51	F57	Sum
50	1500	100	1600
51	1500	300	1800
52	1500	3640	5140
53	1500	6357	7857
54	4385	9208	13593
55	19177	7326	26503
56	24913	9556	34469
57	13202	10357	23559
58	10952	7225	18177
59	13267	6169	19436
60	18832	9264	28096
61	20241	6521	26762
62	25781	14025	39806
63	19984	600	20584
64	19400	5400	24800
65	22600	6000	28600
66	34000	5200	39200
67	37200	7721	44921
68	65272	10644	75916
69	46518	12498	59016
70	23453	13709	37162
71	33698	7945	41643
72	36240	7361	43601
73	28950	5521	34471
74	31936	5898	37834
75	28304	8997	37301
76	27779	9695	37474
77	48538	12864	61402
78	37113	12911	50024
79	29142	13573	42715
80	24602	12530	37132
81	33048	6561	39609
82	44981	9767	54748
83	52222	11162	63384
84	91418	12850	104268
85	104580	13298	117878
86	120941	13225	134166
87	132399	14859	147258
88	188761	15098	203859
89	154754	38308	193062
90	191493	57182	248675
91	191647	46077	237724
92	252636	29339	281975
93	327411	28499	355910
94	226953	44713	271666
95	247787	41652	289439
96	249657	48659	298316
97	239900	65024	304924

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

Whole stock

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	46	7287.5695794	158.4254256	266.28	0.0001
Error	14099	8388.1824792	0.5949488		
Corrected Total	14145	15675.7520586			
	R-Square	C.V	Root MSE		CPUE Mean
	0.464894	72.28723	0.7713292		1.0670339
YEAR	31	3358.3146889	108.3327319	182.09	0.0001
QUARTER	3	24.9910686	8.3303562	14.00	0.0001
AREA	4	1016.9596424	254.2399106	427.33	0.0001
ALB	4	313.6575970	78.4143992	131.80	0.0001
BET	4	38.6052686	9.6513172	16.22	0.0001
Western stock					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	46	5616.8456706	122. 1053407	206.73	0.0001
Error	11029	6514.4367596	0.5906643		
Corrected Total	11075	12131 .2824302			
	R-Square	C.V.	Root MSE		CPUE Mean
	0.463005	67.56348	0.7685469		1.1375182
YEAR	31	2690.9385490	86.8044693	146.96	0.0001
QUARTER	*3*	15.0086370	5.0028790	8.47	0.0001
AREA	4	754.1067575	188.5266894	319.18	0.0001
ALB	4	358.4201219	89.6050305	151.70	0.0001
BET	4	18.0448931	4.5112233	7.64	0.0001
Eastern stock					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	45	3260.7972607	72.4621613	126.46	0.0001
Error	6633	3800.6796528	0.5729956		
Corrected Total	6678	7061.4769135			
	R-Square	C.V.	Root MSE		CPUE Mean
	0.461773	73.05637	0.7569647		1.0361378
YEAR	31	1597.0856139	51.5188908	89.91	0.0001
QUARTER	3	17.0183602	5.6727867	9.90	0.0001
AREA	3	470.5502791	156.8500930	273.74	0.0001
ALB	4	27.7778318	6.9444579	12.12	0.0001
BET	4	45.9060736	11.4765184	20.03	0.0001

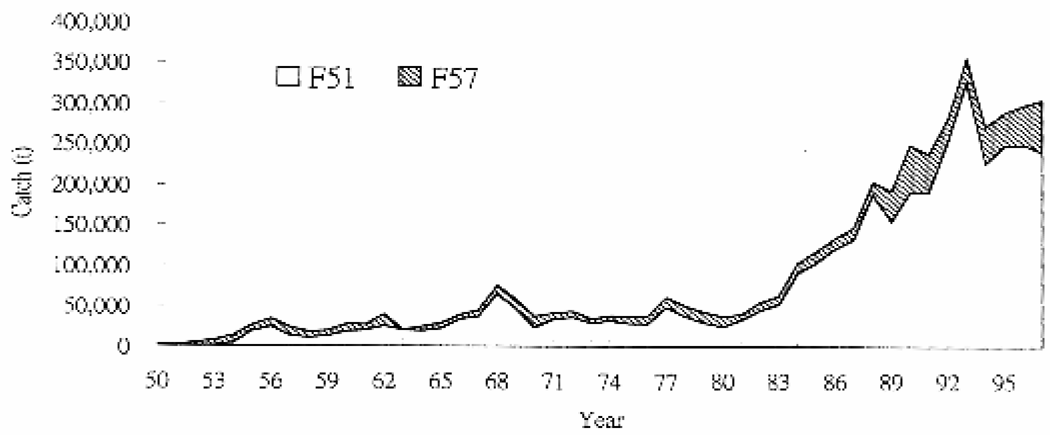

Fig. 1. The yearly catch of Indian yellowfin tuna for the area 51 and 57, 1950-1997.

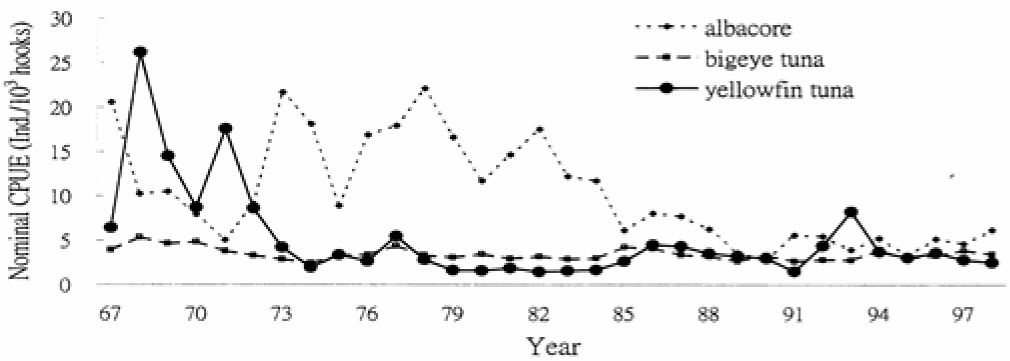

Fig. 3. Nominal CPUE of Indian albacore, bigeye tuna, and yellowfin *tuna for Taiwanese longline fishery, 1967-1998.*

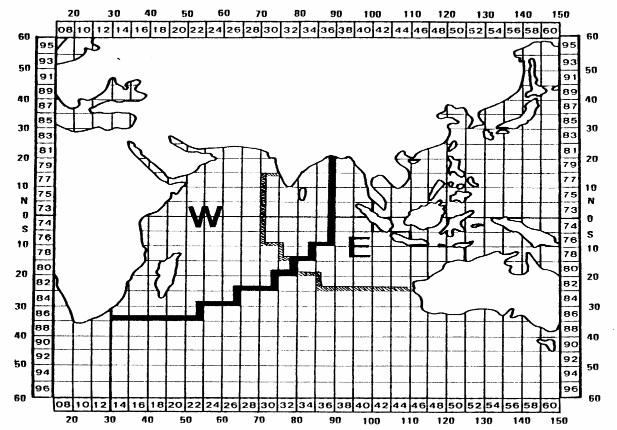

Fig. 2. The boundary of western and eastern sub-stocks (After Nishida ,1992).

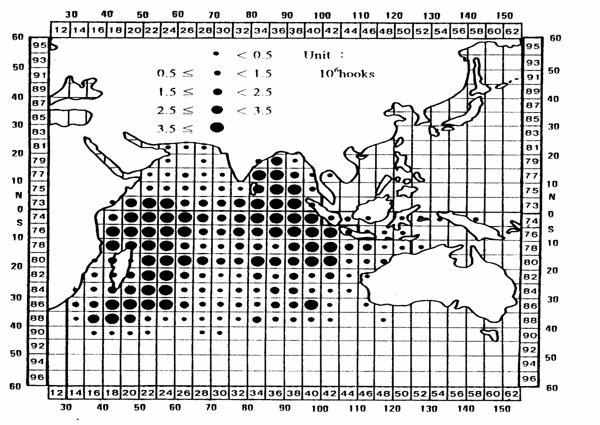

Fig. 4 The nominal effort distribution of averaging 5° x 5° area for Indian yellowfin tuna by Taiwanese longline fishery in 1967 – 1977.

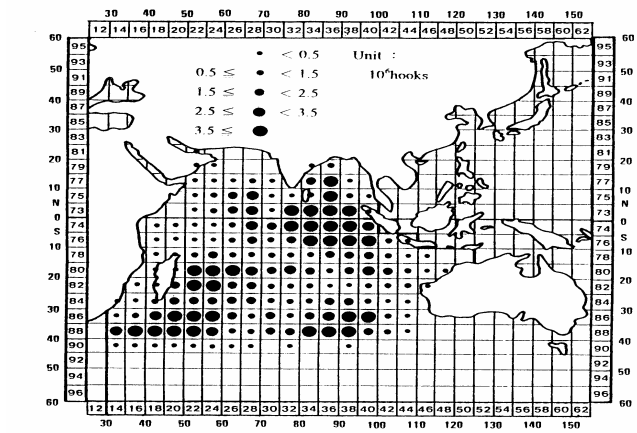

Fig. 5 The nominal effort distribution of averaging 5° x 5° area for Indian yellowfin tuna by Taiwanese longline fishery in 1978 – 1985.

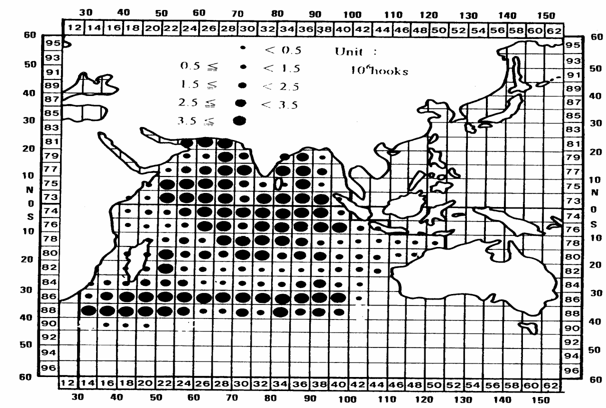

Fig. 6 The nominal effort distribution of averaging 5° x 5 ° area for Indian yellowfin tuna by Taiwanese longline fishery in 1986 - 1991.

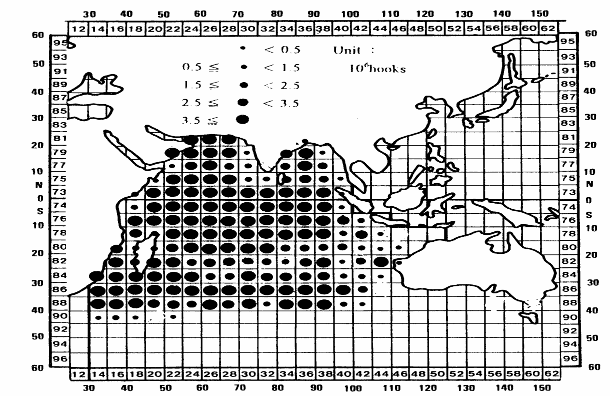

Fig. 7 The nominal effort distribution of averaging 5° x 5 ° area for Indian yellowfin tuna by Taiwanese longline fishery in 1992 - 1998.

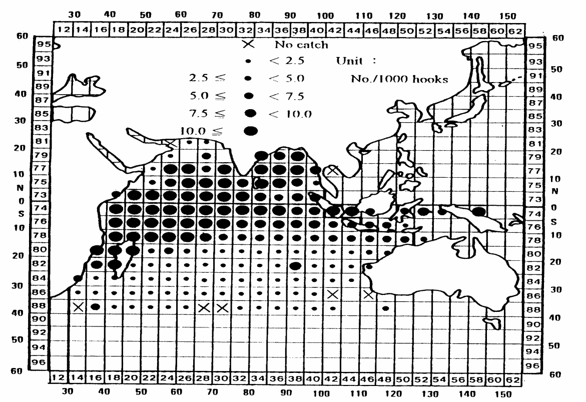

Fig. 8 The nominal catch per unit effort (CPUE) distribution of averaging 5° x 5° area For Indian yellowfin tuna by Taiwanese longline fishery in 1967 – 1977.

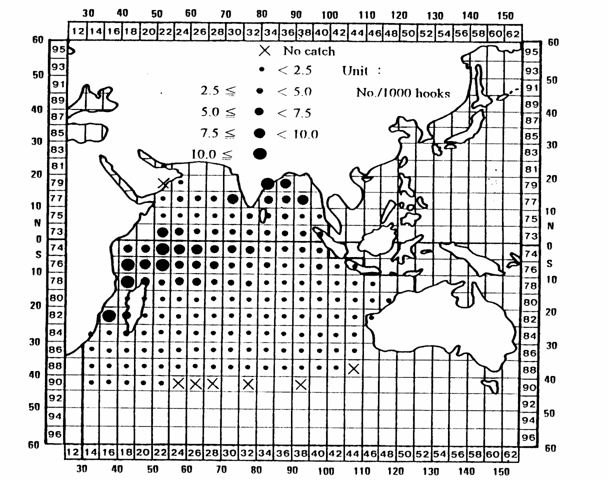

Fig. 9 The nominal catch per unit effort (CPUE) distribution of averaging 5° x 5° area For Indian yellowfin tuna by Taiwanese longline fishery in 1978 – 1985.

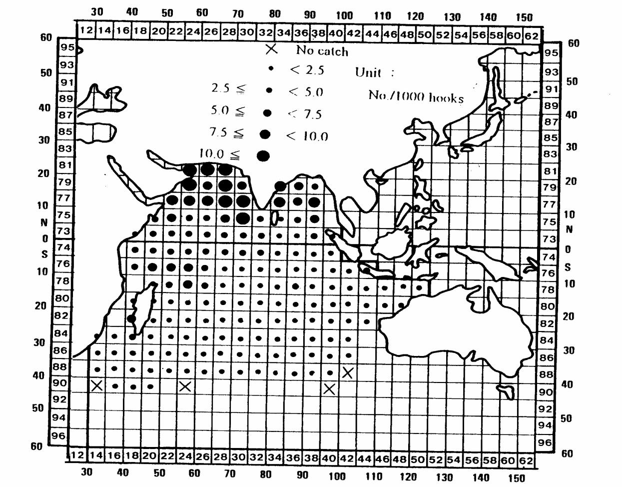

Fig. 10 The nominal catch per unit effort (CPUE) distribution of averaging 5° x 5° area for Indian yellowfin tuna by Taiwanese longline fishery in 1986 - 1991.

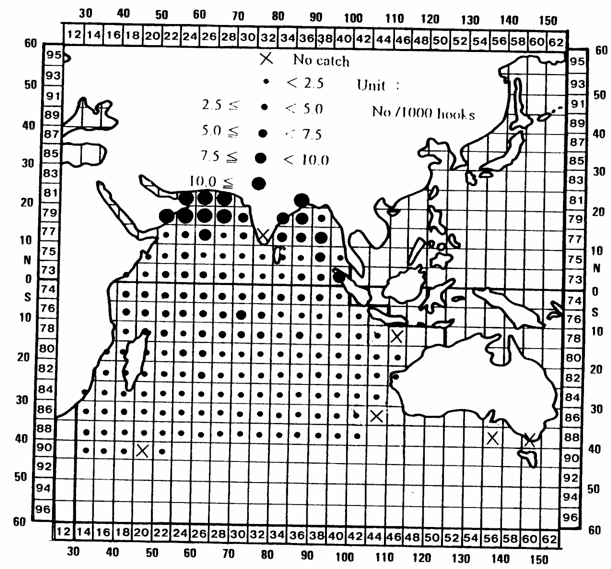

Fig. 11 The nominal catch per unit effort (CPUE) distribution of averaging 5° x 5° area for Indian yellowfin tuna by Taiwanese longline fishery in 1992 - 1998.

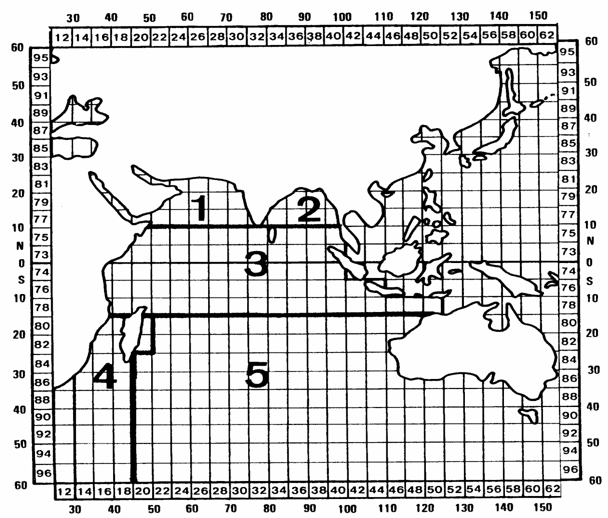

Fig. 12 . Sub-areas used in the standardization of CPUE using GLM model for Indian yellowfin tuna, 1967 - 1998.

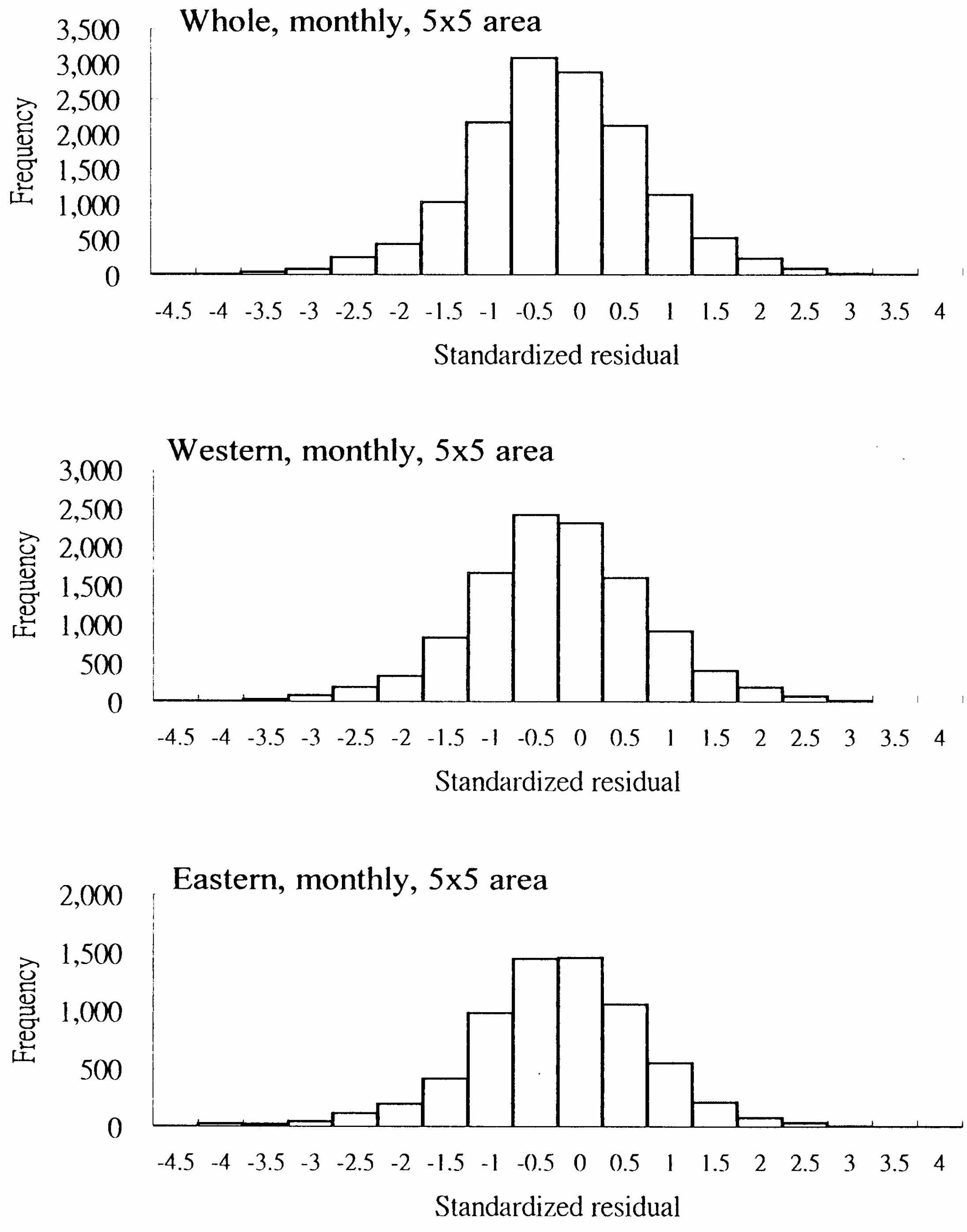

Fig. 13. Histogram of standardized residuals from fitting GLM for showing the normality of standardizing Taiwanese longline fishery for yellowfing tuna in the Indian Ocean, 1967-1998.

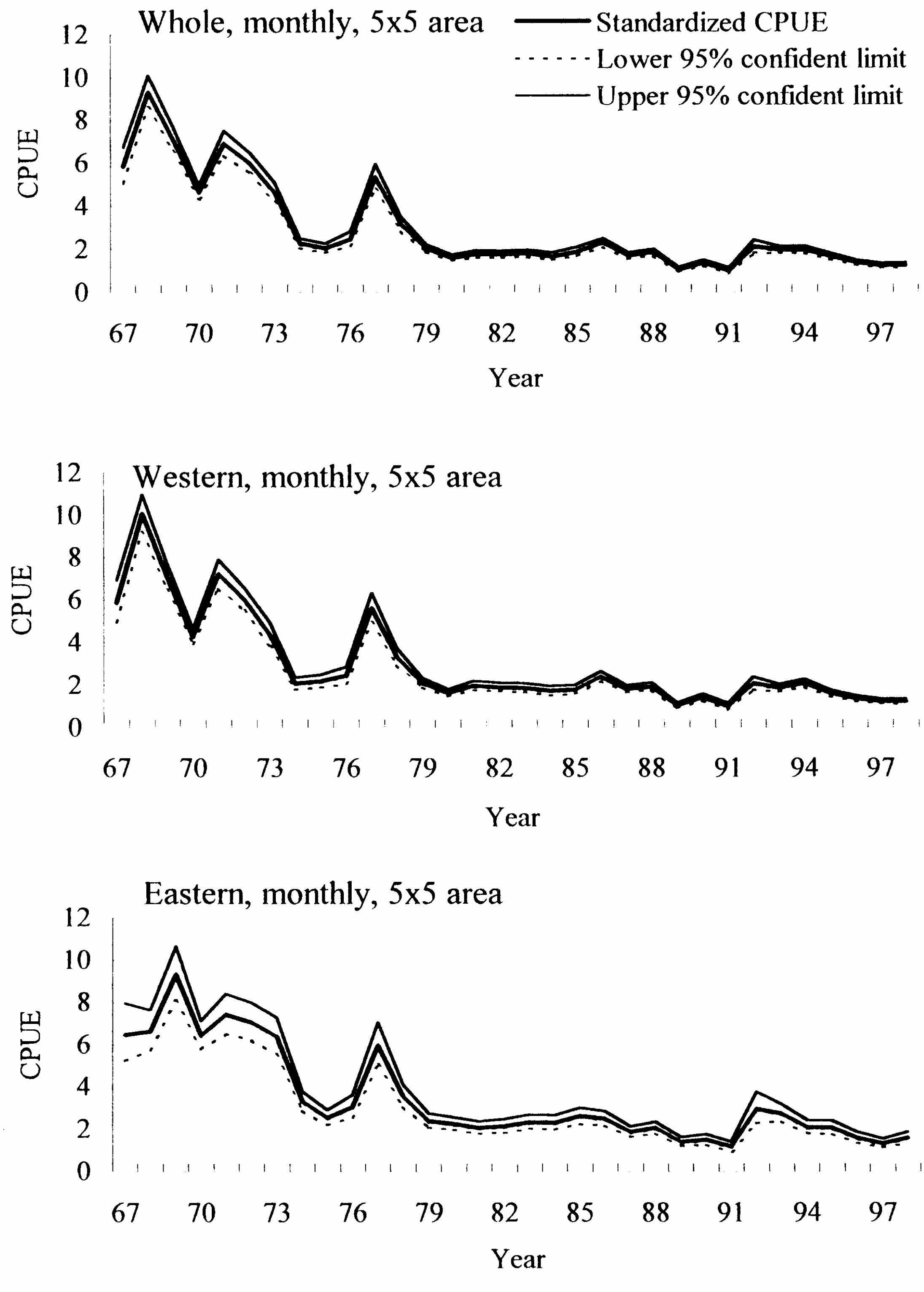

Fig. 14. Standardized CPUE of Indian yellowfin tuna using GLM methoc for Taiwanese longline fishery, 1967-1998.

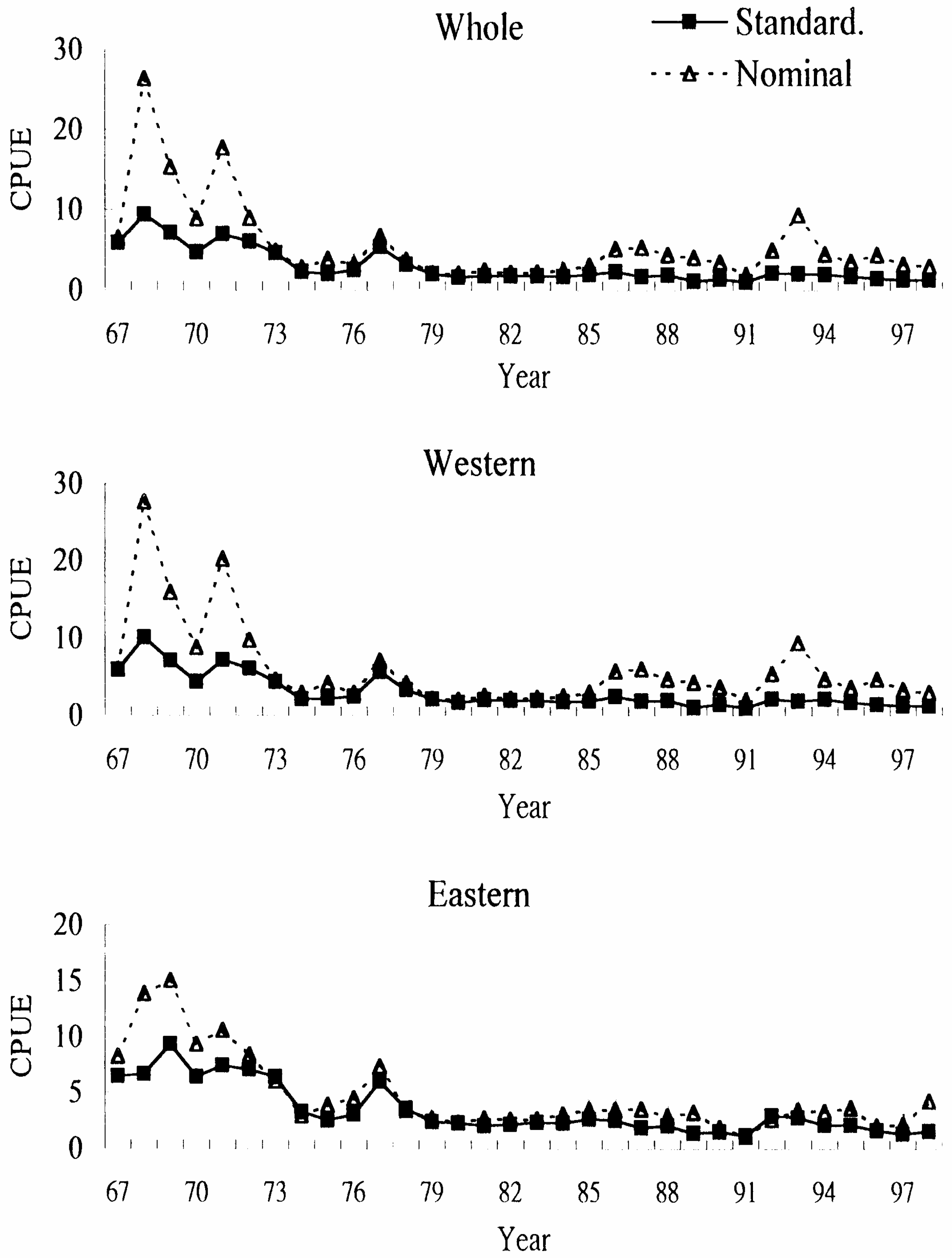

Fig. 15. Comparisons of standardized CPUE and nominal CPUE for whole, western, and eastern stocks.