WORKING PAPER WPYRG3/ 7

Pohnpei, Federated States of Micronesia
June 21-23, 1993

CPUE Analysis of Japanese Fisheries for Yellowfin Tuna in the Central and Western Pacific

S. Tsuji and H. Okamoto

CPUE analysis of Japanese fisheries for
yellowfin tuna in the Central and Western Pacific.

Sachiko TSUJI and Hiroaki OKAMOTO

National Research Institute of
Far Seas Fisheries.

1. Introduction :

Following to the recommendation made at the second meeting of the Western Pacific Yellowfin Tuna Research Group (WPYRG) in 1992, the standardized CPUEs for both Japanese longline and purse seine fisheries were developed. Though the primary objective was to develop an abundance indices, we tried to address to the other two questions set by the Group; the interaction between fisheries and the problem of local depletion.

2. Nominal CPUE of Japanese longline.

The catch and effort distribution by area and nominal CPUE was examined for both longline and purse seine fisheries.

Figure 1 shows the annual change of yellowfin catch and effort of Japanese longline since 1970. Yellowfin catch was stable during most of the 1970s and rapidly increased to close to 70 thousands ton in 1980. After that, the catch have declined gradually but steadily with small fluctuations. Most of catch was come from the WPYRG Area 3 through 5, which corresponding to the area between 20° N and 20° S. The rapid change of catch in 1977 through 1982 was derived from the quick change of Area 3 catch as well as an increase of Area 4 catch.

On the other hand, the effort distributed more evenly among Areas. Especially, the effort deployed to Area 1 and 2, which represented the area from 20° to 40° N, was almost the same as the one deployed to Area 3 to 5. These effort was considered to target mainly on bigeye and albacore tuñas. The effort in Area 6 and 7 should target on bigeye and southern bluefin tunas. The whole effort as well as the distribution of effort among areas did not show big fluctuation by year during the last two decades. The small increase and following decrease of effort in the late 1970s to the beginning of 1980s seemed to correspond to the introduction of deep longlining and the 20% effort reduction by the Government regulation held in 1983.

These characteristics of catch and effort distribution among areas reflected to the nominal CPUE change shown in Figure 3. In this figure, the CPUE was shown in catch in weight by kg per 1000 hooks. Since there had not been observed significant change in effort, it is not surprising to find that the CPUE fluctuated almost the same way as the catch; after the more or less stable period, peak in 1978 and gradual decline thereafter.

In Figure 3, the CPUE when stratifying areas by latitude was also included. The CPUE from the whole areas appeared to be a simple scale down of that from Area 3-5. The concentration of yellowfin catch in Area 3 to 5 and consistency in effort distribution made a contribution from the other areas insignificant. Time area strata which not catching objective species often cause noises for modeling. It is not easy to determine which one should include or reject. However, we decided to use only data from Area 3 through 5 for the analysis in this paper.

Further analysis in this paper was made for CPUE in catch in number per 1000 hooks. The comparison of CPUEs when using catch in number and catch in weight was shown in Figure

4.

3. Nominal CPUE of Japanese purse seine.

The Japanese purse seine catch and effort was shown in Figure 2. Purse seine yellowfin catch steadily increased since 1970 until mid-1980s and leveled off with some annual fluctuation after that. The majority of catch came from Area 3 to 5, the areas between 20° N and 20° S, like the longline catch. The Area 1 also produced a significant part of catch but with a much higher variability. These catches were from domestic purse seiners operating in the Japanese coastal waters.

The effort in Area 3 to 5 increased from 1970 to mid-1980s and became stable after that. In contrast, the effort in Area 1 showed no specific trend except a decline in the recent years. It is not clear whether this recent decline in effort is real or suggesting a continuous reduction of logbook covering rate for domestic fleet.

In this figure, the effort was shown in searching and fishing days. The information on searching days is only available for the fleet operating in a tropical area after 1983. The ratio of whole effort to the effort in fishing days of these fleet varied from 1.25 to 1.71 and did not show any specific trend by year. Therefore, the average ratio by area was applied to raise effort in fishing days to whole effort in Area 3-5. The effort in Area 1 was also raised using the overall average ratio to make the figures comparative with the other areas. However, it should be noted that this correction of effort for domestic fleet did not carry a meaningful logistics, since their operating pattern was completely different from that in the tropical waters.

The nominal CPUEs were shown in Figure 3 for Area 1 and Area 3 to 5 congregated. The CPUE in Area 3-5 increased steadily until the early 1980s possibly according to the cumulative learning of fishing ground and improvement of fishing techniques. After 1980, no specific trend was observed but there seemed to be a periodic fluctuation. The CPUE in Area 1 showed the fluctuation of five to six years periodicity without increase nor decrease of the average level. The periodic fluctuation observed in Area 1 and Area 3-5 CPUEs showed very similar periodicity but differed in phase slightly. It seems important to understand the influence of oceanographic condition to the purse seine CPUE, especially the correspondence with the large-scale oceanographic oscillation such as El Niño and Southern Oscillation, for understanding purse seine CPUE.

Like the case of longline, we decided to analyze only data from Area 3-5. The nominal CPUE in Area 1 showed apparently different pattern from that in tropical area. We have not had sufficient information nor understandings on domestic fisheries operation to incorporate to a model and interpret them. The relationship between the fish distributing in the Northern area and those in the tropical waters is still in question. The quality of statistics is not comparative between domestic and far-seas fleets. However, a CPUE in the marginal area of distribution is often known to reflect a change of stock abundance much more sensitively than that in the center of distribution. At least, we have to improve our understanding on this portion of fishery.

4. CPUE standardization for longline fishery.

At first, the comparison was made for yellowfin CPUEs between deep longline and conventional longline. Figure 5 showed the change of frequency distribution of the number of branches per basket by five year period. Most of the distribution showed distinct two mode with a gap at eight branches per basket. Those two modes were considered to correspond with conventional and deep longline. Therefore, the type of longlining was defined according whether the number of branches per basket was eight and less or not.

The ratio of conventional operations was higher in 1975 but gradually decreased and shifted into the deep longline operations. After 1985, almost all effort shifted to deep longlining and no mode was observed for less than nine branches per basket.

The student's t-test was applied to examine the difference in yellowfin CPUE between conventional and deep longline for 1977 through 1981 data. The results were shown in Table 1. The yellowfin CPUE was higher in deep longline for all year examined. The confidence level of difference was higher than 99.9 % for 1978 and 1979 and 99.5 % level in 1980. But the null hypothesis could not be rejected for 1977 and 1981 data.

The results did not agree with the analysis by Suzuki in 1977 which found no significant differences in CPUE between conventional and deep longlines for every tuna species other than bigeye. The further complicated analysis should be done to solve this discrepancy.

Next, the longline CPUE was standardized using a General Linear Model (GLM) method. The data used here was catch in number per 1000 hooks aggregated by 5 degrees square and month stratum. The effects of year, quarter, area, and interaction between quarter and area were incorporated into the model. The effect of operation type, e.g. deep v.s. conventional operations, was not considered this time. This is mainly because of the time constraint and the difficulty to utilize the original data file which carries the information of number of branches per basket.

The results were shown in Table 2 and Figure 6. All of four factors showed the significant effect on explaining CPUE variation. It was noted the area factor contributed major part for CPUE variation. We felt it necessary to re-examine the area stratification in order to get more accurate indicator of yellowfin abundance.

The standardized CPUE did show the continuous decline from the late 1970s observed in nominal CPUE. However, the CPUE was declining continuously during the last five years. If the further continuous decline would be observed, we should not take this warning too light even when no bad sign could be obtained from purse seine fishery.

5. CPUE standardization for purse seine fishery.

The GLM was utilized to standardize the purse seine CPUE. The Japanese logbook required to identify the catch of yellowfin bigger than 10 kg from the other. These two size categories were analyzed separately. The data was aggregated into three different levels, 1) by 1 degrees square and month, 2) by 5 degrees square and quarter, and 3) by WPYRG Area and quarter. The first aggregation was rejected after several trial runs. This was mainly because of the problem in handling cells with low effort, which tended to show zero catch.

Figure 7 showed the distribution of nominal CPUE and log CPUE for small and large yellowfin tuna by the second level of aggregation. While the small YFT CPUE showed more or less balanced distribution, the CPUE of large YFT showed multi-modal distribution and could not be approximated by statistical distribution.

Both additive and multiplicative models were considered. The factors incorporated to a model were years, quarter, area, ratio of skipjack to total catch, ratio of log set to all positive sets made, and interactions between several selected factors. A concentration factor was also included for model when using the area-quarter aggregated data. A concentration factor was defined as a ratio of efforts deployed to the one degree squares where searching or fishing were made in the previous day to a whole efforts. After trial runs, all interactions were dropped except the one between quarter and area. Thereafter, the final models were selected by aggregations and model types by dropping factors stepwise. The process of selecting factors were summarized in Table 3.

Figure 8 was the relative change of CPUE standardized using these selected four models. All models showed the basically same trend, a periodic up and down for small fish and gradual increase for large fish. Since the smaller aggregation should contain the more detailed information, we decided to use the second level of aggregation for the final model. The selection between multiplicative and additive models was made based on the distribution patterns of residuals shown in Figure 9.

The finally selected models were multiplicative for small fish and additive for large fish. The selected versions were shown with bold line in Figure 9 and final standardized CPUE trend was shown in Figure 10. Both models incorporated the effect of year, log set ratio and skipjack ratio.

There was no specific trend observed for overall yellowfin CPUE except possibly a very slight increase. However, the increase of large yellowfin CPUE apparently contradicted with the recent declining trend of longline CPUE. The GLM standardization is a sum of corrections for the effects what we regard as an influential to CPUE. If there are some factors changing with time but not incorporated model, all of the effect by these factors are appended to the year effect. One of the example most critical in developing abundance indices is a change of effective effort induced by improvement of techniques as well as experiences. An increase of effective effort by improvement of efficiency produce an imaginary increasing trend of standardized CPUE, which may be the case observed in purse seine large fish CPUE.

The oceanographic factor should be the other important factor to be included for purse seine CPUE model. It is well known that yellowfin ratio in catch varies year to year corresponding to the environmental conditions. If we can find an effective indices, the periodicity observed purse seine CPUE can be removed to reveal a better figure of the change of fish abundance.

6. Effect of purse seine catch to the longline CPUE.

The purse seine fishery had expanded quickly to exceed the highest longline catch without showing any distinctive decline of longline CPUE. However, Suzuki mentioned about the reduction of longline CPUE in the area where purse seiners heavily operated and cautioned for the possibility of local depletion. We followed his work to provide more detailed information on the influence of purse seine activity to longline catch. Nominal CPUE was used for this analysis.

Figure 12 showed the change of spatial distribution of longline CPUE for all WPYRG area by five year period. It was recognized that the CPUE between 5° S and 20° N declined substantially during 1980-1984 to 1985-1990 period, while the other area did not show remarkable changes.

Figure 13(a) showed the declining rate of longline CPUE in Area 4 when a linear change was assumed during 1980 through 1990. Black circles denoted a decline and white one an increase. The large decline occurred in the small area between 5° N and 5° S and 140° to 160° E, which concurred to the area where the Japanese purse seine catches were made (Figure 13(b)). On the other hand, the CPUE in high latitude than 10° N or S showed stable or rather increasing trends.

Fork length distributions were compared among the same time period for the selected three areas shown in Figure 14. Grid 1 represented the area whose CPUE was stable or increasing, while Gird 2 and 3 were representatives of areas with declining CPUE. The results was shown in Figure 15. Grid 1 produced very similar size distributions among four time period. However, for Grid 2 and 3, the distribution for the 1985-1990 period differed from the distribution of the other time period. The mean and median shifted to larger side. The substantial minimum size also shifted from 80 cm for 1970-1984 to 90 cm in the most recent time period, while there was no change occurred in the substantial maximum size. This means that the shifts of mean and median was not caused by shifting of targeting size but by a decline of ratio of small fish in catch. These changes were less distinctive for Grid 3 than Grid 2 but still visible. The change of distribution was looked like that the lower part of distribution was scraped off with a knife.

The Japanese purse seiners operating in the area caught fish of mainly 30 to 100 cm. Although no direct evidences were obtained, it was easily assumed the purse seine activity caused the change of size distribution of longline catch in the area. This is still very preliminary analysis and too early to derive some conclusion at this stage. However, we are very concerned about the effect of purse seine activities especially on the local depletion and hope to involve the US data to the analysis in near future.

7. Summary

The yellowfin CPUE for longline and purse seine fisheries were standardized using GLM method for WPYRG Area 3 to 5.

The GLM for longline CPUE incorporated the effects of year, quarter, area, and area/quarter interaction, and the area factor provided the major contribution for explanation of residuals. The resulted standardized CPUE showed no specific trend except the continuous decline of last five years.

The purse seine CPUE was calculated two size categories in separate. The final GLM model incorporated the effects of year, log set ratio and skipjack ratio. The standardized CPUEs showed periodic fluctuation without any distinct trend for small fish, but steady increase for large fish, which contradicted with the results obtained from longline CPUE. The possible reason of this contradiction was discussed.

The difference of yellowfin CPUE by type of longline operations was recognized but the further comprehensive analysis was not made this time.

The decline on longline CPUE and decrease of ratio of small fish in longline catch was recognized in the 1985-1990 period, exclusively in the area where purse seines operated heavily. The problem of influence of surface catches and local depletion should be addressed in near future.

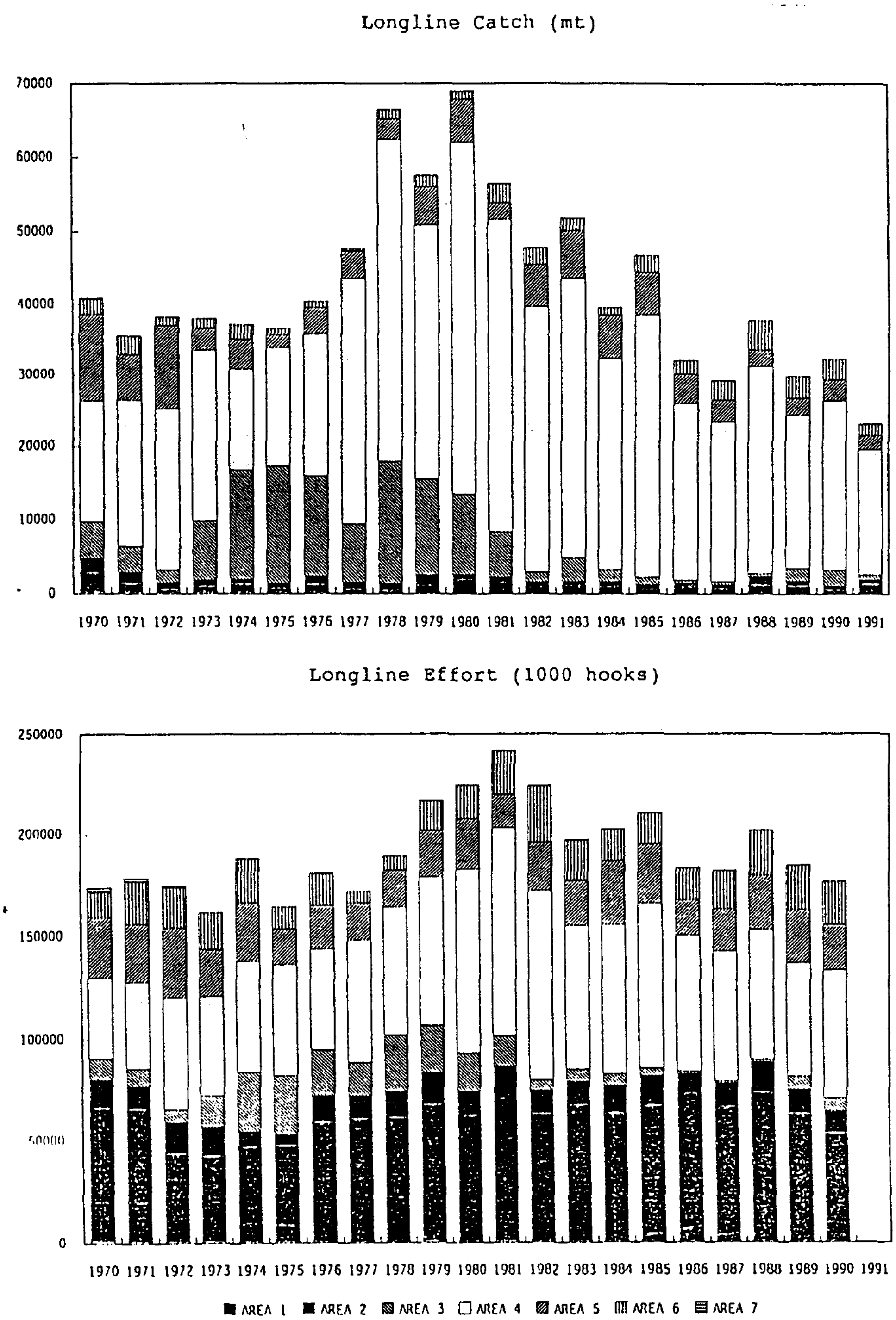


Figure 1. Catch and effort of Japanese longline by WPYRG area.

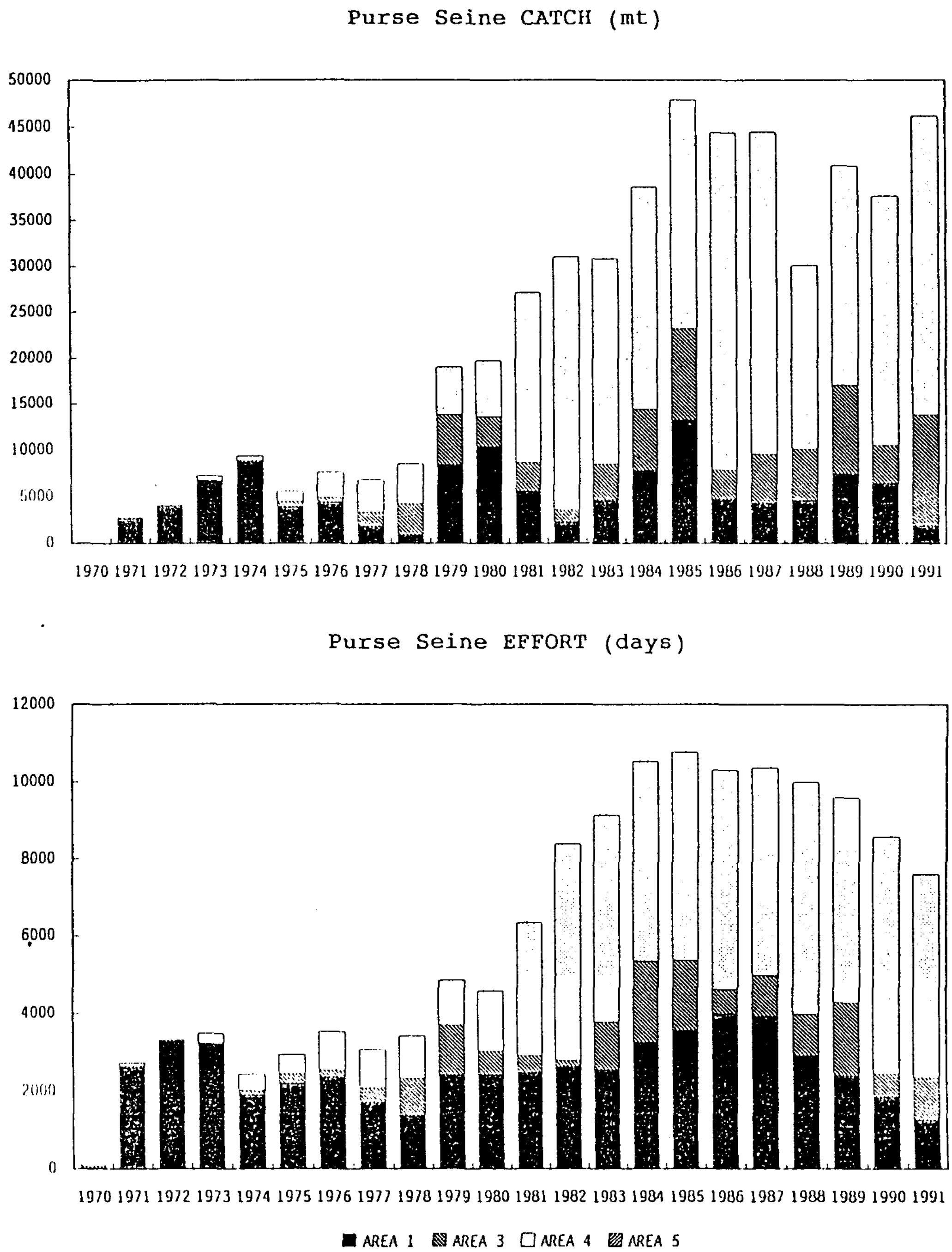


Figure 2. Catch and effort of Japanese purse seine by WPYRG area.

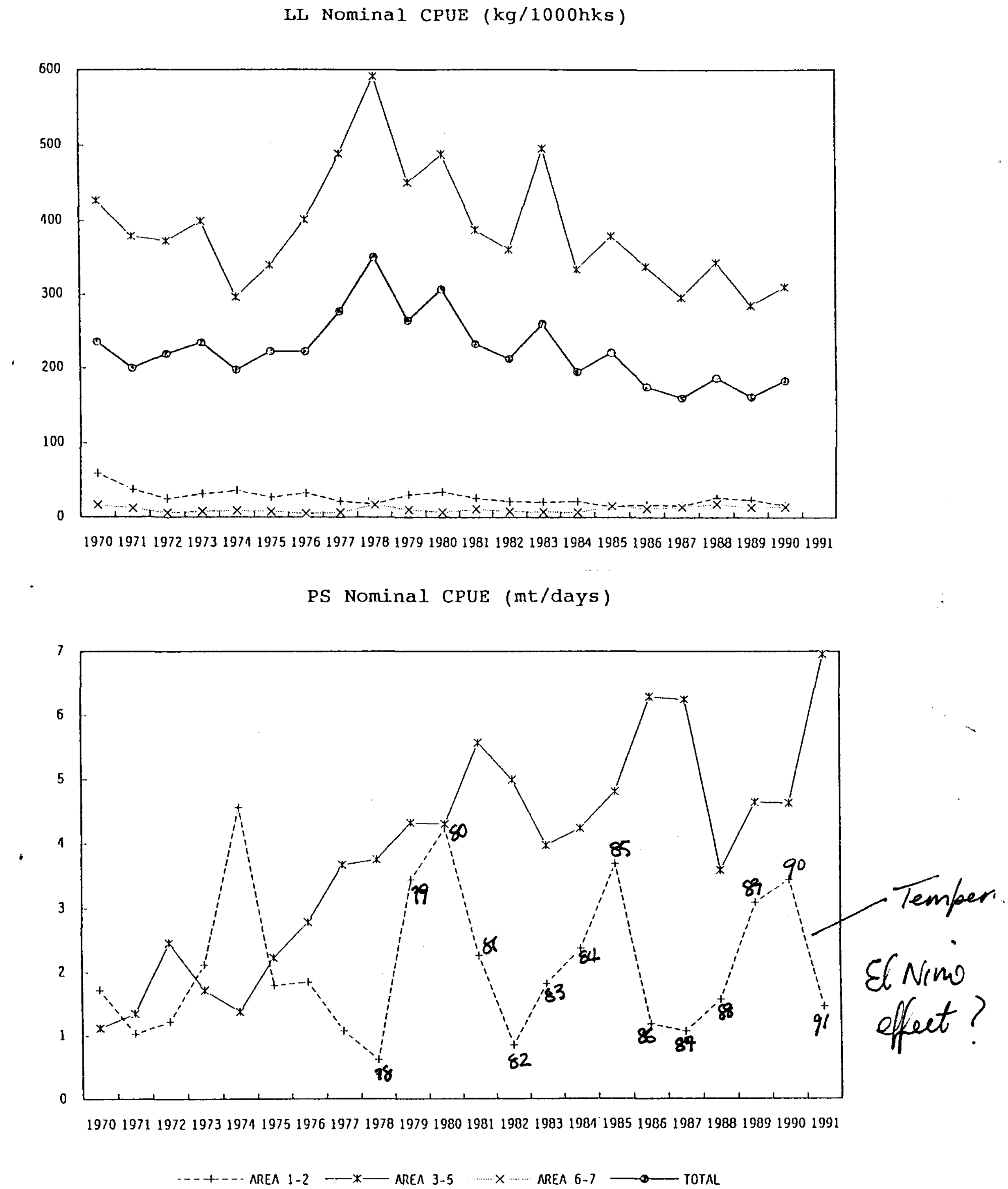


Figure 3. Nominal CPUEs of Japanese longline and purse seine fisheries. Whole WPYRG areas were stratified into three according to the latitude.

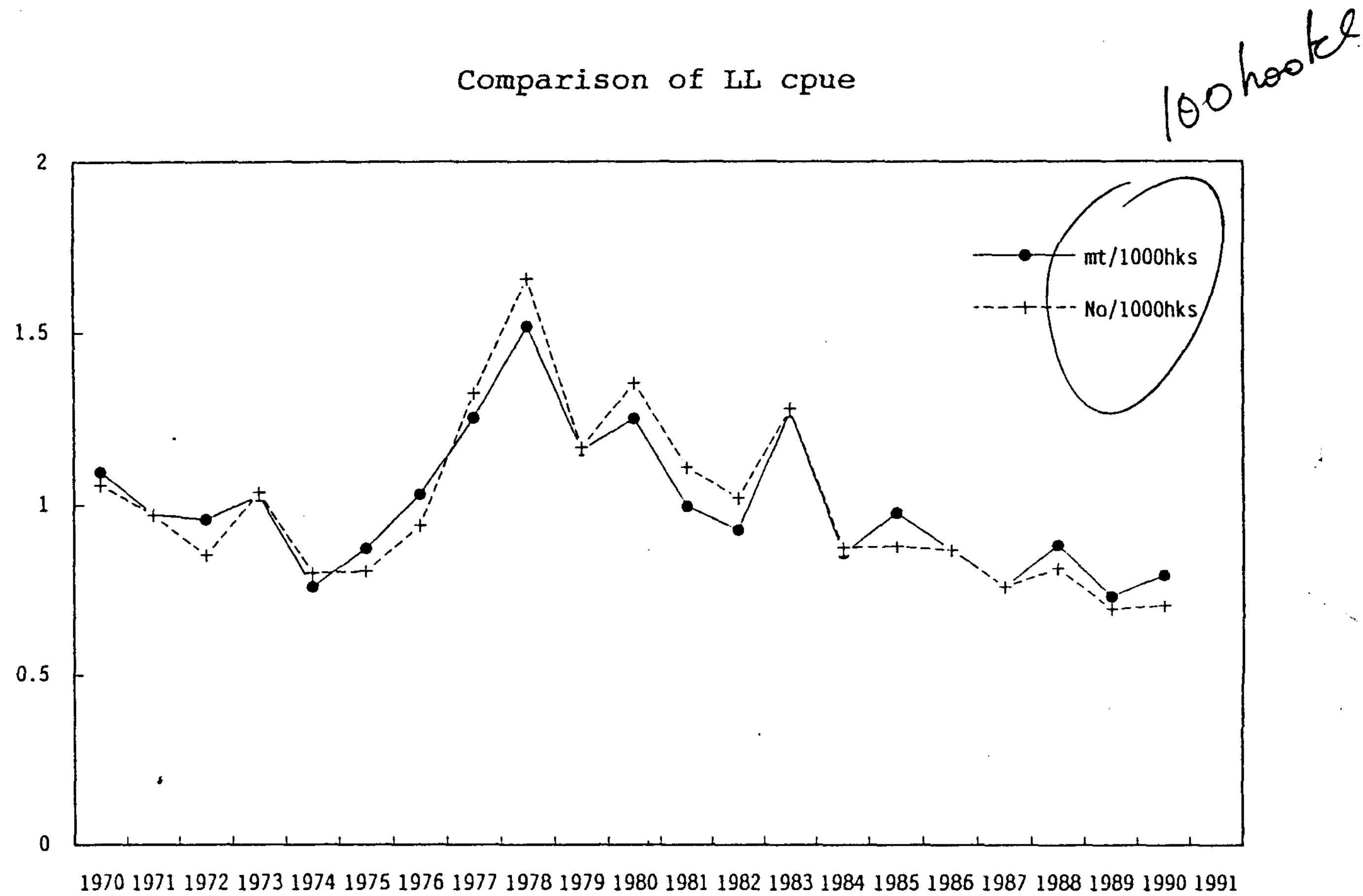


Figure 4. Comparison of longline CPUEs when using catch in weight and catch in number.

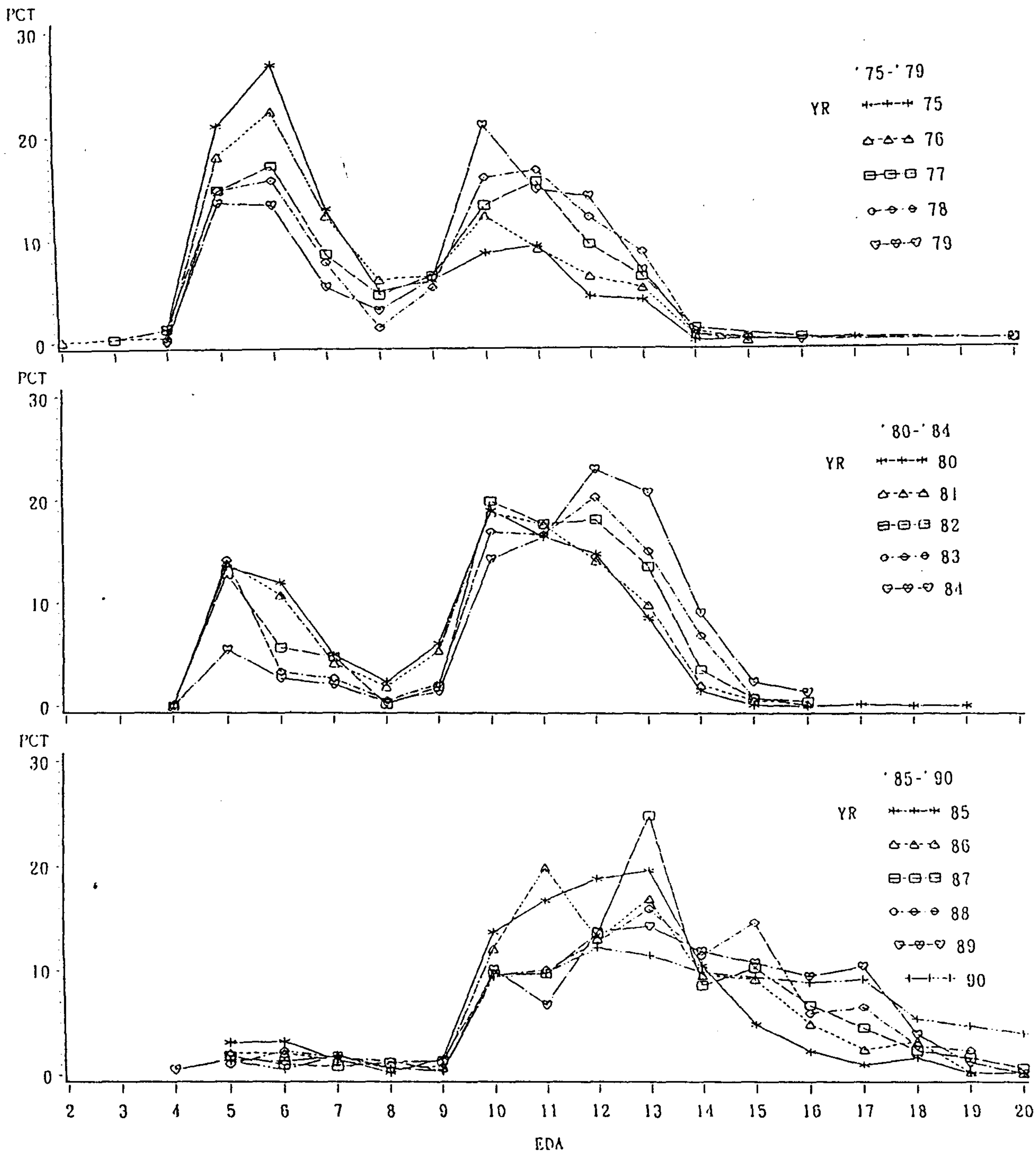


Fig. 5. Change of the number of branches per basket.

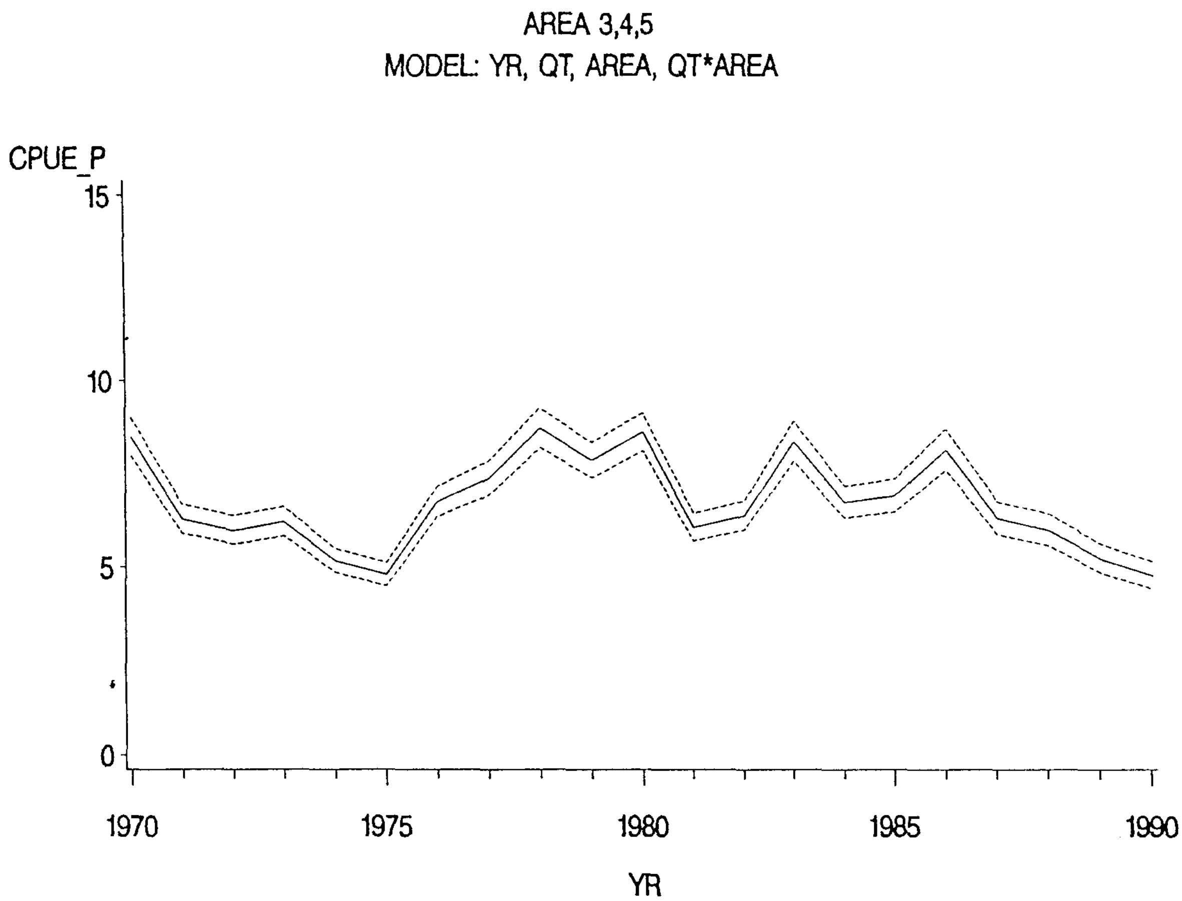


Fig. 6. Standerdized CPUE of yellowfin tuna by longliners with GLM method (Model includes facters year, quater, area and quater/area interaction). Catch data from WPYF-3, 4, 5 areas were used.

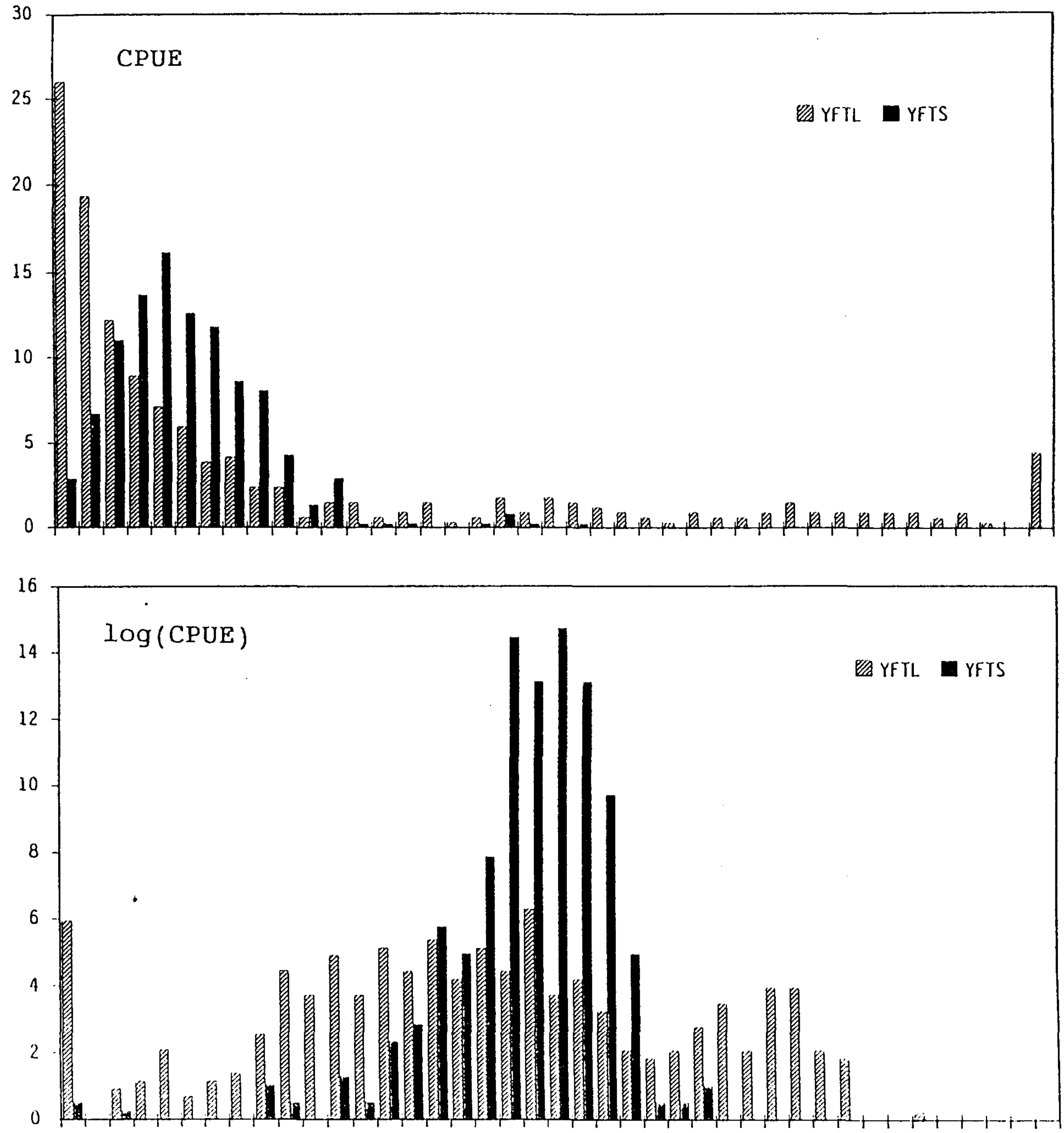


Figure 7. Frequency distribution of purse seine CPUE. Nominal CPUEs were calculated for each 5 degrees square by quarter. 'YFTL' denoted CPUE of yellowfin bigger than 10 kg and 'YFTS' for CPUE of yellowfin smaller than 10 kg.

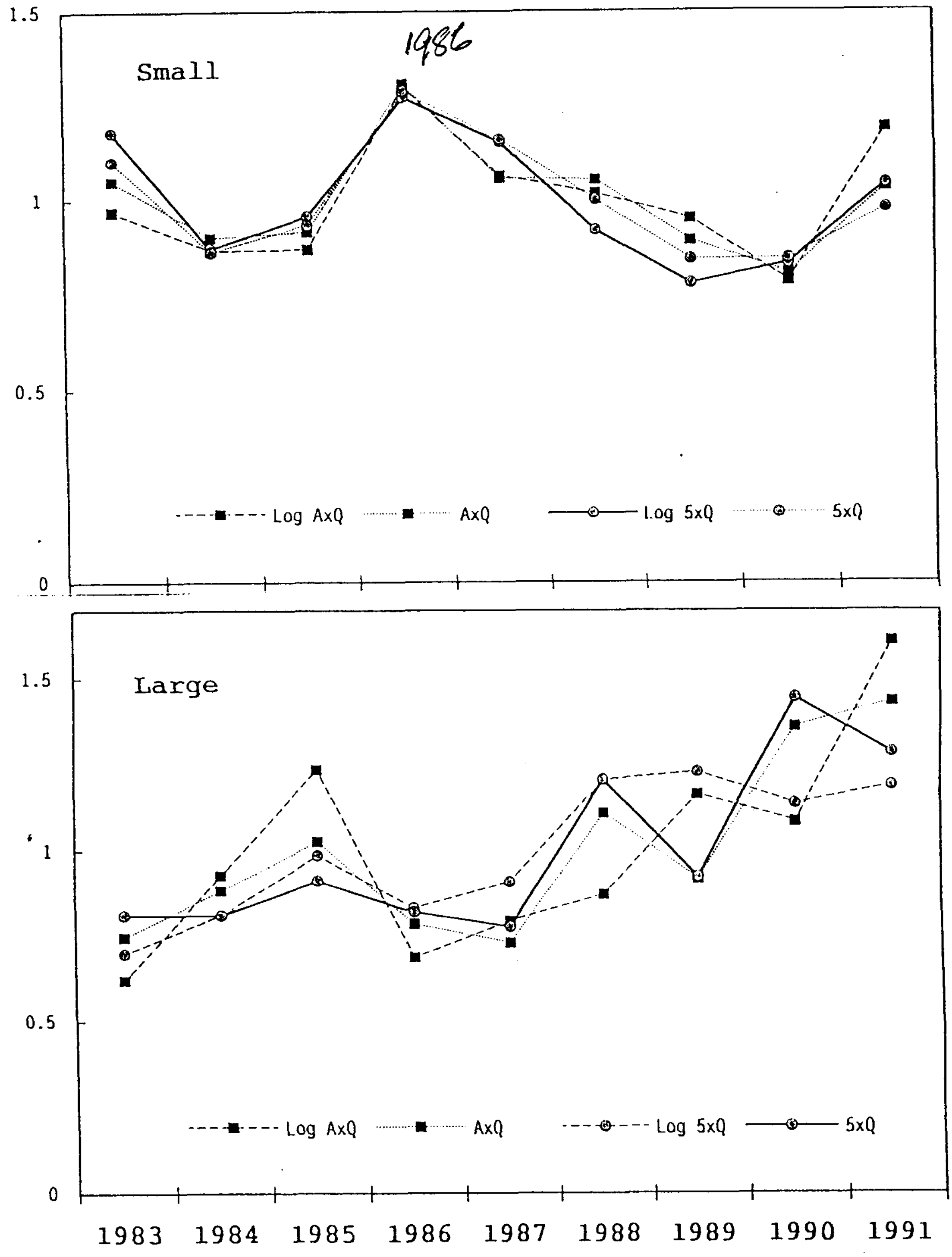


Figure 8. Comparison of relative CPUEs standardized by multiplicative (denoted with 'LOG') and additive GLMs using two different level of aggregated data. 'AxQ' corresponded to the data aggregated by WPYRG area and quarter and '5xQ' for the data aggregated by 5 degrees square and quarter. Bold line showed the model finally accepted.

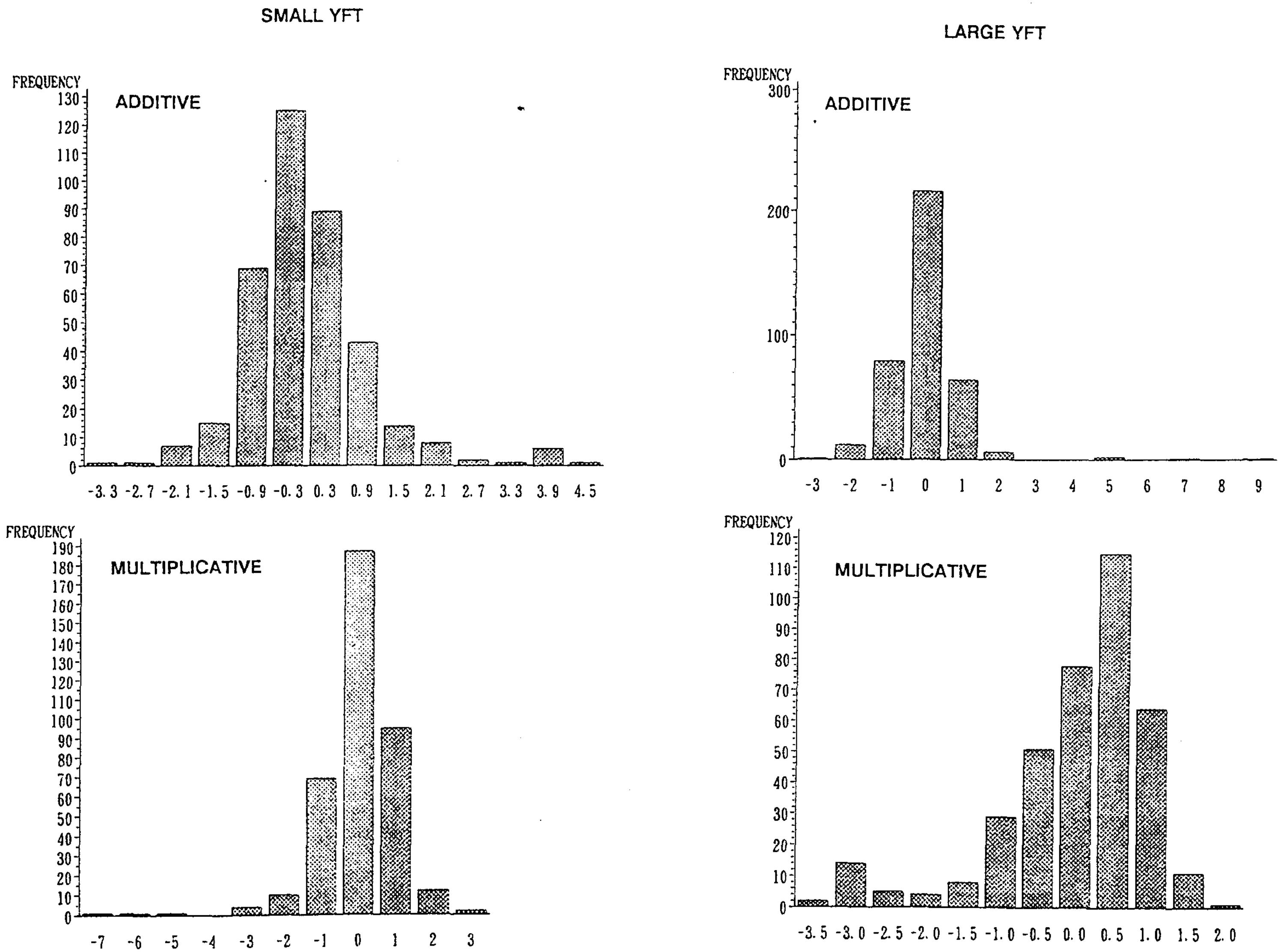


Figure 9. Comparison of residual distribution between additive and multiplicative models.

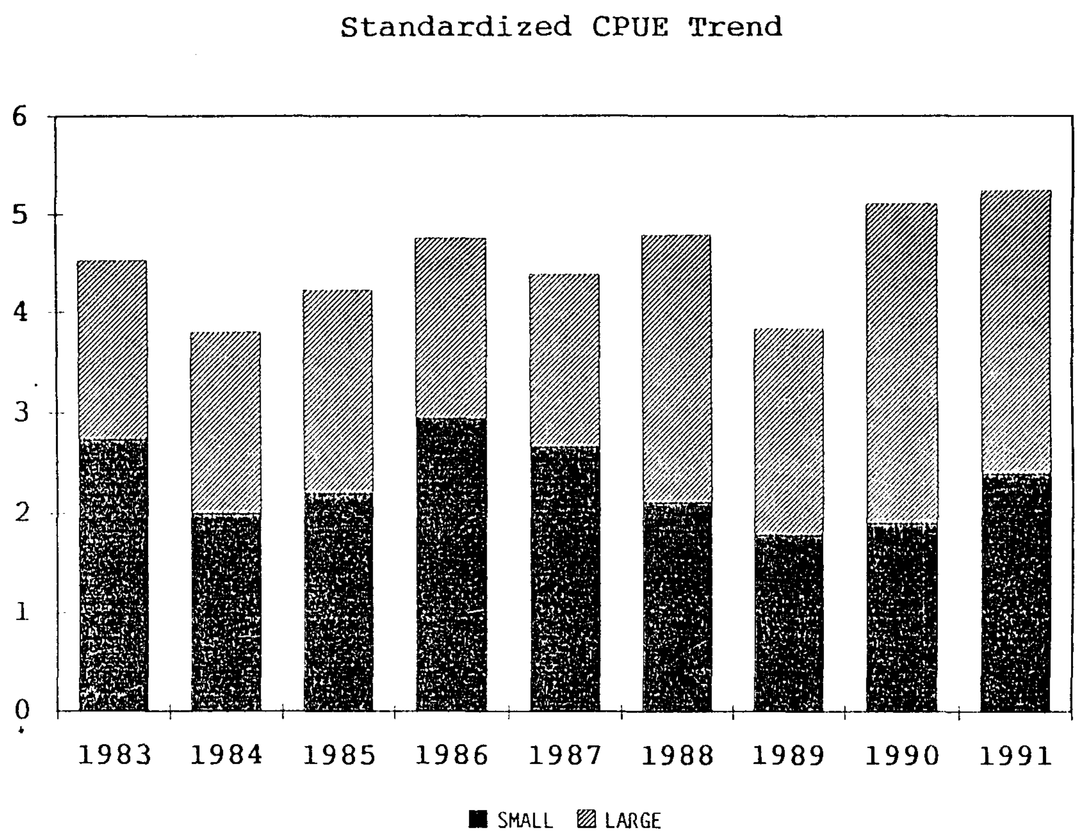


Figure 10. Yellowfin CPUE for purse seine fishery standardized using GLM.

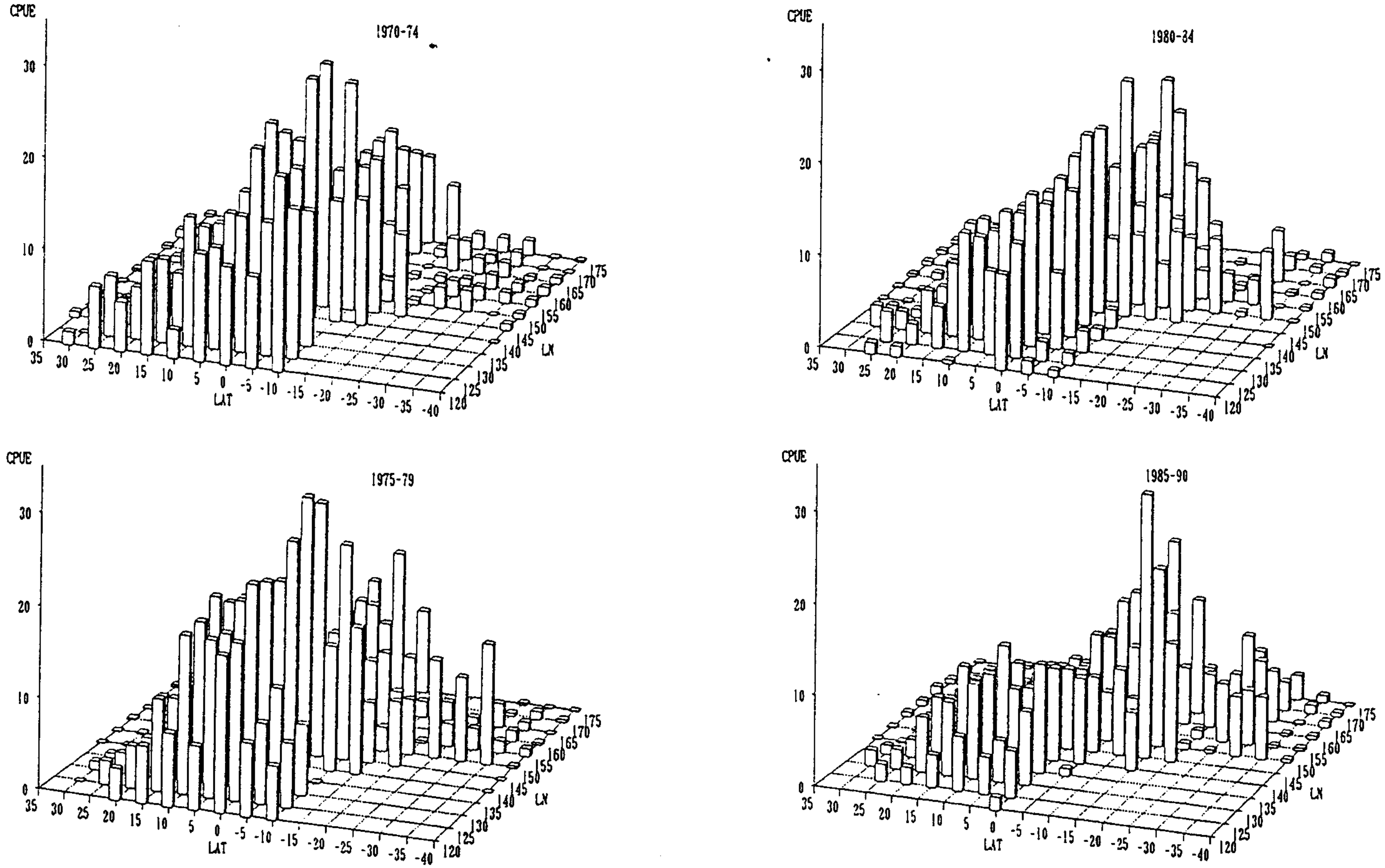
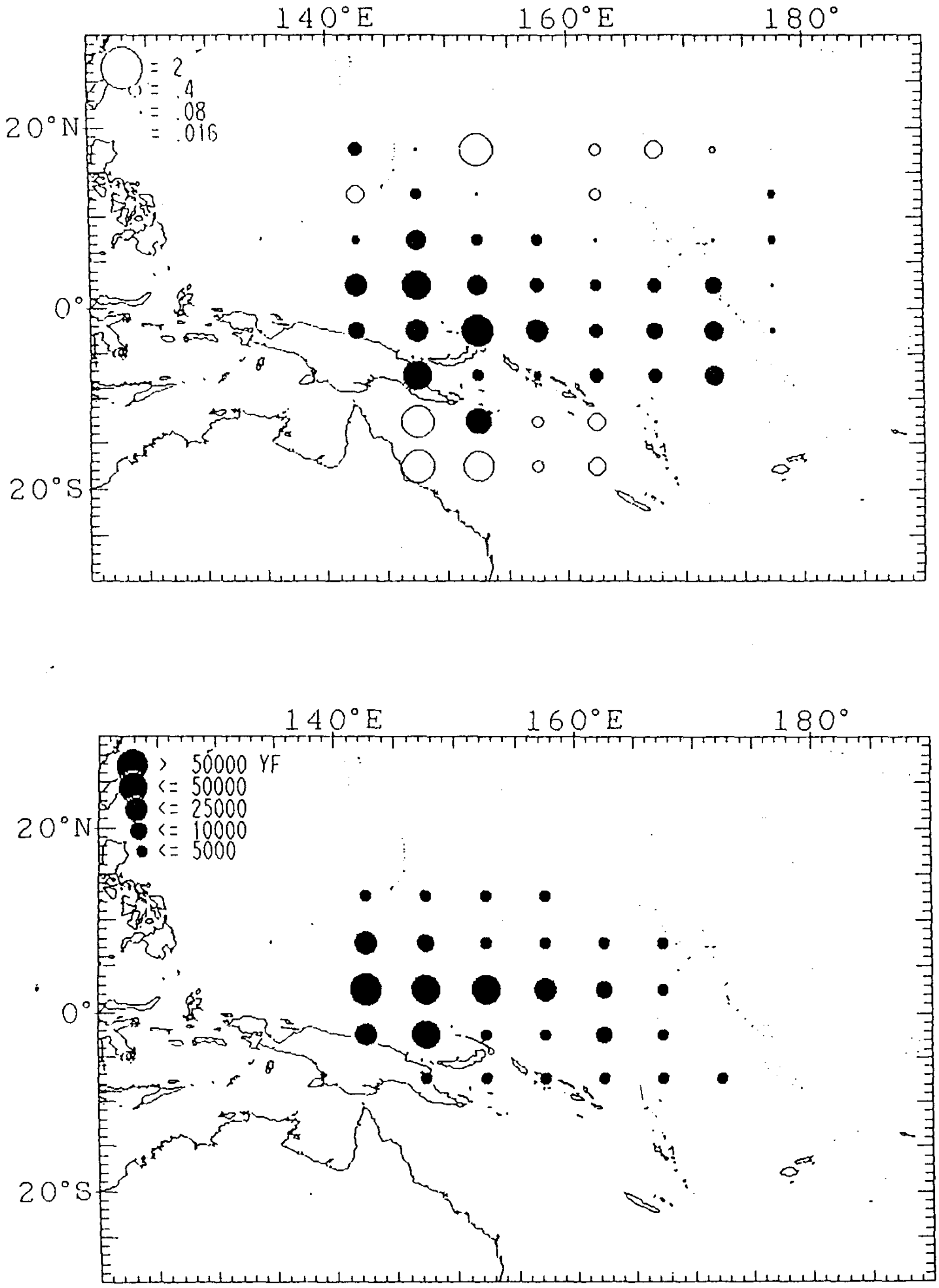


Fig. 12. The change of spatial distribution of longline CPUE by time period.



Figs. 13. The correspondance between longline CPUE and distribution of Japanese purse sein catch. Upper figure shows the change of longline CPUE represented by slope of regression line of CPUE for 1980-1990 by 5 degree square. Open and closed circles correspond ~~negative~~ positive and ~~positive~~ negative change in CPUE respectively. Lower figure shows distribution of yellowfin catches by Japanese purse seiners in the same area.

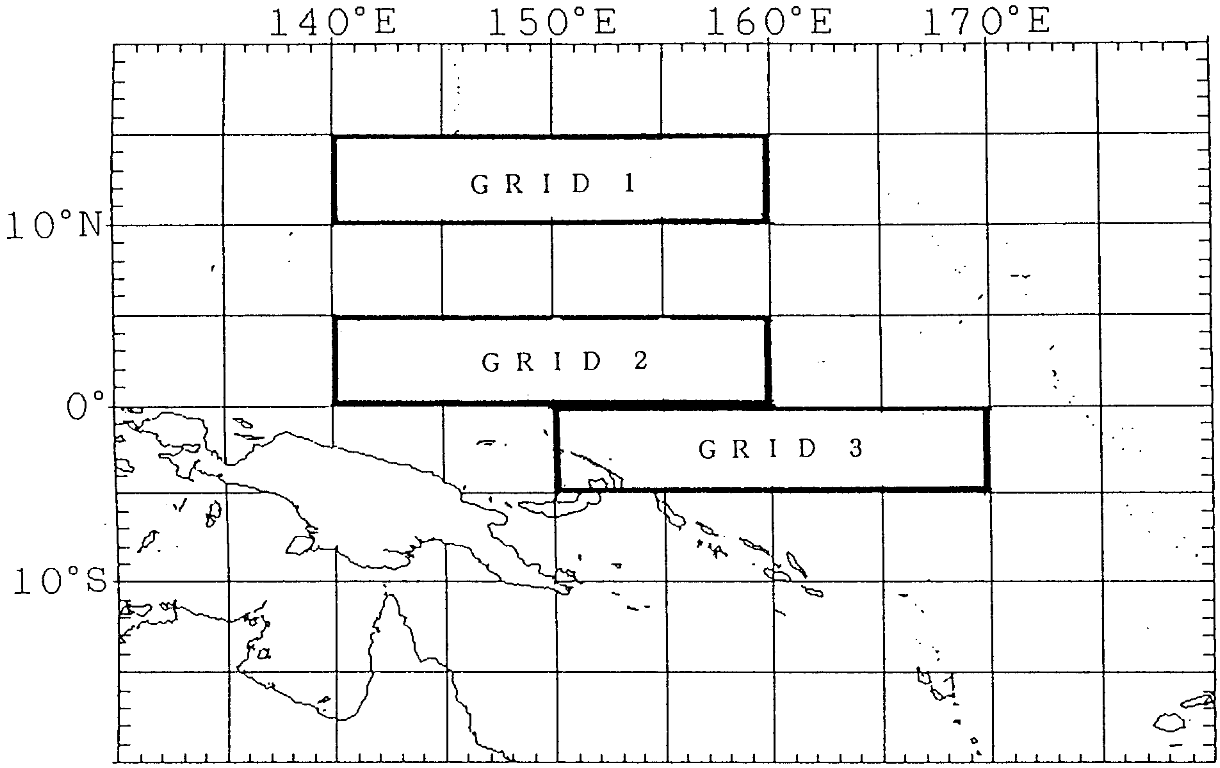


Fig. 14. Three grids used for comparison of fork length frequency.

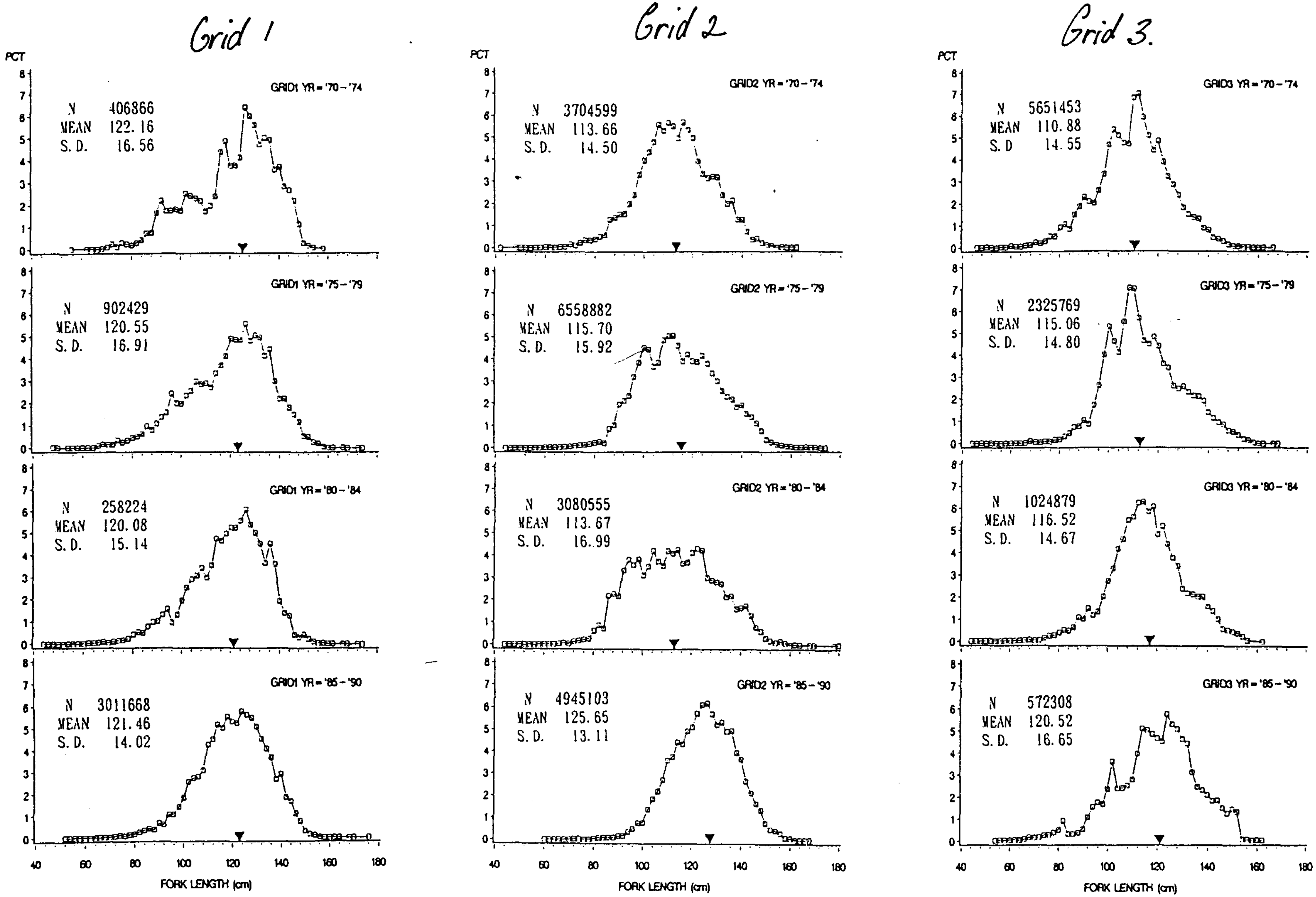


Fig. 15. Fork length frequency for three grids by 5 years time period. Black triangle on the X axis shows the median in each graph.

Table 1. T-test for comparison of CPUE for yellowfin between deep(DEP) and regular(REG.) longline. Operation was defined by the number of branches per basket, corresponding 8 brabches and less and 9 branches and more.

YEAR	TYPE	N	MEAN	S.D.	T	D.F.	Prob>T
1977	REG.	1935	13.693	13.56	2.125	2965.5	0.0336
	DEP.	1586	12.604	14.42			
1978	REG.	1177	18.163	16.939	6.047	2363.1	0.0001
	DEP.	1777	14.440	15.517			
1979	REG.	1627	12.775	9.36	4.427	2264.0	0.0001
	DEP.	1927	11.174	9.68			
1980	REG.	1104	13.869	10.37	2.784	2425.5	0.0054
	DEP.	2251	12.764	11.61			
1981	REG.	994	10.672	8.24	1.824	1986.1	0.0683
	DEP.	2210	10.090	8.57			

Table 2. Results of GLM analysis applied to CPUE for yellowfin for WPYF-3, 4, and 5 areas.

Source	F value	Pr > F
YEAR	32.50	0.0001
QUATER	24.14	0.0001
AREA	1960.04	0.0001
QUATER*AREA	25.00	0.0001

Table 3. Process to select factors incorporating into model.

Models for small yellowfin for data aggregated by 5 degree square and quarter.

Additive 5xQ : YFT_S				
YR	0.0001	0.0001	0.0001	0.0001
Q	0.3797	0.3912	0.4583	
A	0.4376			
Q*A	0.0078			
SET	0.0001	0.0001	0.0001	0.0001
SKJ	0.0001	0.0001		0.0001
Mod F	12.55	15	9.78	19.02
R*R	0.369	0.346	0.241	0.339
MSE	1.279	1.295	1.393	1.297

Multiplicative 5xQ : YFT_S				
YR	0.0001	0.0001	0.0001	0.0001
Q	0.0042	0.0045		0.0081
A	0.3536			
Q*A	0.278			
SET	0.0001	0.0001	0.0001	0.0001
SKJ	0.0001	0.0001	0.0001	
Mod F	14.39	17.96	23.33	14.42
R*R	0.402	0.3882	0.3861	0.319
MSE	0.5891	0.5926	0.5912	0.6242

Table 3 (cont.)

Models for large yellowfin for data aggregated by 5 degree square and quarter.

Additive 5xQ : YFT_L				
YR	0.0001	0.0001	0.0001	0.0001
Q	0.1565	0.1568	0.5142	
A	0.0044			
Q*A	0.0037			
SET	0.0001	0.0001	0.0001	0.0001
SKJ	0.0001	0.0001		0.0001
Mod F	45.38	58.94	10.63	74.63
R*R	0.6794	0.6755	0.2569	0.6679
MSE	1.987	1.988	3.005	2.003

Multiplicative 5xQ : YFT_L				
YR	0.0001	0.0001	0.0001	0.0012
Q	0.1518	0.1541		0.3506
A	0.2133			
Q*A	0.4118			
SET	0.0001	0.0001	0.0001	0.0001
SKJ	0.0001	0.0001	0.0001	
Mod F	19.89	25.33	32.3	5.41
R*R	0.4815	0.4722	0.4654	0.1497
MSE	1.196	1.2004	1.2032	1.5216

Table 3 (cont.)

Models for small yellowfin for data aggregated by area and quarter.

Additive AxQ : YFT_S								
YR	0.0016	0.0079	0.0098	0.0012	0.0013	0.0021	●0.0015	0.0009
Q	0.0793	0.1412	0.1536	0.0741	0.0752	0.0906		
A	0.2688	0.3238	0.3333					
Q*A	0.1146	0.1892						
SET	0.1115			0.0002	0.0002	0.0004	0.0001	0.0001
SKJ	0.2631			0.4077				0.4111
CONC	0.1704	0.5025	0.9848	0.0193	0.0276			0.021
Mod F	3.41	2.23	2.24	4.26	4.45	4.11	5.55	5.43
R*R	0.5365	0.3939	0.3344	0.5111	0.4995	0.4555	0.4461	0.4988
MSE	0.8233	0.9241	0.943	0.8153	0.8177	0.8457	0.8321	0.8046

Multiplicative AxQ : YFT_S									
YR	0.0016	0.0015	0.0018	0.0011	0.0013	●0.0009	0.0014	0.0028	0.0032
Q	0.0234	0.0229	0.0255	0.199	0.0219		0.0228	0.032	0.0341
A	0.0958	0.0952	0.0997	0.09		0.0867			
Q*A	0.1175	0.1164	0.1244						
SET	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
SKJ	0.4696						0.7587		0.7708
CONC	0.096	0.1139		0.0288	0.0096	0.0274	0.0083		
Mod F	3.88	4.08	4.05	5.01	5.08	6.33	4.71	4.44	4.04
R*R	0.5688	0.562	0.5411	0.5517	0.5325	0.5372	0.5364	0.4746	0.4754
MSE	0.3567	0.3561	0.3612	0.3506	0.355	0.347	0.3566	0.3731	0.376

Table 3 (cont.)

Models for large yellowfin for data aggregated by area and quarter.

Additive AxQ : YFT_L							
YR	0.0001	0.001	0.0001	0.0001	0.0001	0.001	0.0009
Q	0.2462	0.2382				0.6538	0.6481
A	0.3577						
Q*A	0.0275		0.0546				
SET	0.0001	0.001	0.0001	0.0001	0.0001	0.0001	0.0001
SKJ	0.0001	0.001	0.0001	0.0001	0.0001		
CONC	0.0951	0.0724	0.0951	0.1377		0.7797	
Mod F	14.86	19.23	14.86	22.94	24.5	4.97	5.46
R*R	0.8346	0.8253	0.8346	0.8079	0.8007	0.5269	0.5263
MSE	1.22	1.209	1.22	1.236	1.249	1.973	1.957

Multiplicative AxQ : YFT_L							
YR	0.0001	0.0001	0.0001	0.0001	0.0001	0.0009	0.0046
Q	0.2241				0.2629	0.31	0.615
A	0.0041	0.0047	0.0054				
Q*A	0.4207						
SET	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0004
SKJ	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	
CONC	0.0838	0.0815			0.0072		
Mod F	10.93	14.99	15.52	13.5	12.11	11.14	3.44
R*R	0.7878	0.753	0.7399	0.6887	0.7484	0.7141	0.4118
MSE	0.5694	0.5822	0.5925	0.6428	0.5978	0.6318	0.8986